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Final Rail Joint Report

The Welded Rail Joint Committee of the American Bureau of Welding and the American Electric Railway Association has just issued a final report of 350 pages in which are summarized the results of the most comprehensive series of investigations ever undertaken in the welded rail joint field. The research work extended over a period of ten years. The results are of interest to other industries and applications of welding.

Limited finances have made it only possible to print an edition of a few hundred copies which are being placed on sale at $1.00 a copy as long as they last. Members of the Society are given first preference to purchase a copy and those desiring same should place their order at once with the Secretary.

International Acetylene Association Meeting

A technical meeting unlike any ever held before in the United States is planned by the International Acetylene Association as a feature of its Annual Convention to be held in Philadelphia, November 16th, 17th and 18th.

This unique session will be held Wednesday evening, November 16th in the Main Auditorium of the Penn Athletic Club, 18th Street and Rittenhouse Square, Philadelphia. An industrial drama in three acts and five scenes will be presented, portraying vividly the technical and practical factors of plant rehabilitation in the industrial field under today's economic conditions.

It has been said that this type of technical meeting has been used with important success in Soviet Russia as a part of the development of the Five Year Plan and in the support of other major industrial projects. A cast of leading scientific and engineering authorities will assure the technical soundness of the program and its dramatization will represent a unique experiment in the appeal of this type of exposition to the American industrial public.

Professor Frank P. McKibben, President, AMERICAN WELDING SOCIETY will preside at this session. The Vice-Chairman is to be H. S. Smith, Chairman of the Technical Committee of the International Acetylene Association. John M. Carmody, Editor of *Factory and Industrial Management*, will take part in the program, as will Louis Fine, Superintendent of Welding, Bethlehem Steel Corporation.

Among the speakers at the formal technical sessions of the Association's Convention are included:

Samuel Vauclain, Chairman of the Board, Bethlehem Steel Corporation; James H. Critchett, Director of Research, Union Carbide and Carbon Research Laboratories, Inc.; J. J. Feichter, Heintz Manufacturing Company, Philadelphia; Fred Mauerer, Air Reduction Sales Company; Dr. S. Lewis Land, Heating and Piping Contractors National Association; F. P. Hankins, Assistant Vice-President, Pennsylvania Railroad; Lt. E.W. Clexton, Naval Aircraft Factory, Philadelphia; A. B. Chapman, Chesapeake and Ohio Railroad; James W. Cottrell, Technical Editor, *Commercial Car Journal;* Lt. Alford Williams, Johns Hopkins, Vice-President, American Steel and Wire Company; E. L. Quinn, Jones and Laughlin Steel Corporation; K. V. Wheeler, General Manager, Lebanon Steel Foundries; Christian A. Wills, General Manager, William B. Pollack Company; Everett Chapman, Lukenweld Company; Professor Bradley Stoughton, Lehigh University; Herman Ullmer, The Linde Air Products Company; R. F. Helmkamp, Air Reduction Sales Company; D. E. Roberts, The Linde Air Products Company; Dr. Ancel St. John, St. John X-Ray Corporation; and Dr. Gilbert Doan, Lehigh University.

All sessions of the Association's Convention are freely open to any interested individual, and all who have occasion to consider the welding process in any of its phases are urged to attend. In addition to the speakers listed on the program, practically all of the leading authorities on the oxyacetylene welding process will take part in the formal or informal discussions of the various papers.

President Addresses Engineers of Pennsylvania

Professor Frank P. McKibben recently delivered an address at Harrisburg before the Engineers Society of Pennsylvania at which were present 180 engineers of this Society. Professor McKibben also talked before the West Virginia University to students, professors and local engineers.

OBITUARY

The following resolutions were adopted by the Executive Committee of the AMERICAN WELDING SOCIETY at its meeting held on November 1st in regard to the death of Mr. Harry N. Van Deusen.

"WHEREAS: In the death of Mr. Harry N. Van Deusen on May 15, 1932, the AMERICAN WELDING SOCIETY lost one of its honored Sustaining Members, and

"WHEREAS: Mr. Van Deusen, during the past 25 years, had made valuable contributions to engineering knowledge through his investigations of engineering materials, particularly electrical insulating materials; therefore be it

"RESOLVED: That the AMERICAN WELDING SOCIETY hereby expresses the deep sorrow of its members in his death, that this resolution be recorded in the records of the Society through publication in the JOURNAL and that a copy be transmitted to his family and to the Bell Laboratories, Inc."

(*Signed*) Frank P. McKibben,
President
(*Signed*) M. M. Kelly
Secretary

BOUND VOLUMES

Members desiring to build up their libraries on welding are urged to place an order for a bound volume for 1932 at once. Price, $6.50 plus postage.

A few additional volumes still remain for the year 1931. This particular volume is one of the outstanding welding publications of the world. It contains a wealth of information on all phases of welding. It includes a Subject and Authors' Index.

HOW TO WELD

Starting with the January issue, the Meetings and Papers Committee plan to include a section in the JOURNAL giving full information on how to weld specific jobs. These descriptions will be brief and will cover reasons for welding, how the work was done, testing or examination of the finished product and advantages of welding. Any special welding kinks will also be covered

Members who have knowledge of some specific interesting jobs which could be briefly described are urged to prepare these for publication in the JOURNAL. One or two photographs may be included where necessary.

A question and answer column will also be included. Here are some of the first questions to be covered:

1. How do you weld high-carbon steel of 0.50 and over?
2. How do you weld pure silver?
3. Are there any precautions necessary in gas cutting steel of 0.50 and over?
4. Has any one experience in welds subjected to impact blows such as driving piles?

SECTION ACTIVITIES

CHICAGO

The first fall meeting of the Chicago Section of the AMERICAN WELDING SOCIETY was held the evening of Friday, October 21st, in the Palmer House, and was preceded by a dinner attended by twenty-seven. Mr. H. C. Boardman of the Chicago Bridge & Iron Works gave an illustrated lecture on "Plate Fabrication" in which he discussed the design of many different types of tanks and discussed the shop and field welding procedure employed in their erection.

DETROIT

A meeting of officers was held October 17th at the Detroit Engineering Society clubhouse to arrange programs for coming meetings. The following is a tentative schedule:

December 1st—A meeting to be held at the plant of the American Blower Corp., Detroit. The subject for this meeting will be a paper on "Modern Methods in Oxyacetylene Machine Cutting." Speaker will be announced later. After the meeting demonstrations of cutting will be given by representatives of different manufacturers.

The week of January 16th—Joint meeting with the Highway and Building Congress.

February 3rd—Joint meeting with Detroit Engineering Society, American Society of Civil Engineers and AMERICAN WELDING SOCIETY.

February 16th—Paper to be presented on the welding of special alloys.

March 23rd—Paper to be presented on modern methods of fabricating air-conditioning equipment.

LOS ANGELES

A special meeting of the Los Angeles Section was held Tuesday evening, August 9th, at the University Club. Mr. F. M. Randlett, Pacific Coast Manager, Robt. W. Hunt Company, presented pictures and a paper prepared by Mr. F. Eder, of the same company, on "Inspection and Tests of Welding in Structures." The author outlined procedures in training, testing and supervision of welders as an important and necessary part of satisfactory welding.

Mr. F. P. Glick, President, Welded Products Co., Inc., Bell, Cal., gave a talk, "Fabrication of Steel Shapes by Use of Mechanical Gas Cutting and Electrical Arc Welding." An early review of the potential possibilities of this newer means of fabrication was given by the speaker, who led up to present accomplishments. Mr. Glick presented samples of the work his company is doing to successfully compete with castings.

Mr. V. M. Goode, C.M.M., U. S. S. *Medusa*, read the first prize paper in the Lincoln Arc Welding Competition, written by Lt.-Comm. H. N. Wallin, U.S.N., and Lt. Henry A. Schade, U. S. N., entitled "The Design and Construction of an Arc Welded Naval Auxiliary Vessel." A lively discussion followed.

PHILADELPHIA

A most successful meeting of the Philadelphia Section was held on October 17th. Mr. Wm. D. Halsey, Asst. Chief Engineer, Boiler Division, the Hartford Steam Boiler Inspection & Insurance Company, spoke on "What Is a Good Weld?" Mr. E. A. Burt, Chief Engineer of the Heine Boiler Co., Inc., and Mr. T. M. Jackson, Electrical Engineer, Sun Shipbuilding and Dry Dock Company, spoke on "How to Weld to Meet the Boiler Code."

PITTSBURGH

The 1932–1933 seasonal activities of the Pittsburgh Section of the AMERICAN WELDING SOCIETY was inaugurated during the evening of October 19th, with a meeting held at the Fort Pitt Hotel at which two papers were read. A. F. Davis, Vice-President of the Middle Eastern Division of the A. W. S., who is also Vice-President of the Lincoln Electric Company, read a paper on "American Welding Society and Its Place in the Industry." Mr. Davis first gave the audience a general picture of how extensively welding is used in the metal marking industry, by showing a series of slides of a diversified line of welded products. This was followed by a very thorough and complete description of the organization, purpose, functions and benefits of the AMERICAN WELDING SOCIETY.

The second paper was presented by G. N. Sieger, Metallurgical Director of P. R. Mallory & Co., Inc., Indianapolis, Ind., on the subject of "Welding and Cutting—Elkonite and Carboloy." Mr. Sieger described the design and functions of electrodes for various types of resistance welding. He particularly stressed the importance of proper cooling of the electrodes in order to increase the output per electrode.

A joint meeting of the Pittsburgh Section of the A. W. S. and the Engineering Society of Western Pennsylvania will be held at the William Penn Hotel on the night of November 30th, at which A. E. Gibson, Vice-President of the Wellman Engineering Co., will present a paper on the "Application of Welding to the Manufacture of Heavy Mechanical Equipment."

PORTLAND

The first meeting of the season of the Portland Section was held at the Star Film Exchange on October 6th at 7:45 P.M. The subject of the meeting was a discussion of recent improvements in electric welders. Mr. E. B. Thompson, representing the Lincoln Electric Co. and Clyde Equipment, distributors, read a paper describing the newest offering in Lincoln "Shielded Arc" welders. Mr. R. C. Cooper next explained the technical improvements in the latest Westinghouse A.C. Welder. Mr. Cooper is Sales Engineer with the Westinghouse Elec. & Mfg. Co. Mr. H. L. Ernstrom, representing J. E. Haseltine Co. distributors for General Electric Co., waived his right to the floor and advised that he would let the "talkies" speak for him. The talkie was shown and explained the construction of G. E. Electric Welders. This reel was followed by one dealing with the development of Atomic Hydrogen Welding which showed several practical illustrations of how the method was used in the manufacture of G. E. products. Discussion followed.

SAN FRANCISCO

The October meeting was held Friday night, October 28th at 7:30 P.M. at the Athens Athletic Club, Oakland. The speaker of the evening was Mr. R. E. Brown of the Electro Metallurgical Sales Corp., who talked on "The Practice of Welding Chromium, Chromium Stainless Steels and Chromium Nickel."

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirteenth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to the Society's headquarters.*

SERVICES AVAILABLE

A-184. Welder desires position. Have had experience in pipe line work, acetylene and arc, also railroad, machine and boiler work, airplane, shipbuilding and aluminum welding.

A-185. Welder desires position. Have acted as salesman, engineer and demonstrator for Quasi-Arc Co. and have also been employed by several welding companies.

Automobile Repair Welding

By A. F. KEOGH

✦Paper presented at the Fall Meeting of the American Welding Society in Buffalo, Oct. 3 to 7, 1932, by A. F. Keogh, Sound Welding Co., Inc., New York.

THERE are thousands of automobile repair shops, service stations and machine shops throughout the country which use welding for repair and reclamation work in the maintenance and repair of automobiles, trucks and buses. A well-equipped welding shop, such as can be found in most communities, has ample facilities for almost any type of welding or cutting job which may be encountered. Prompt and efficient service can be rendered for any customers who have repairs to be made. Many bus operators, fleet owners and automobile service stations, finding themselves unable, through lack of space or other reasons, to provide a central welding shop on the premises, arrange for neighboring contract welding shops to do all their welding repair work under an agreement contract, thus receiving the benefits of the experience and service which the established contract welding shops can offer.

To the automotive repair industry, welding has assumed an importance never previously reached in this field, because the cost of maintenance and repair work to autos, trucks and buses has seldom, if ever, been scrutinized with a more critical eye than at the present time. Versatility of the welding process has nowhere been of greater avail than in the automotive repair shop. Practically all of the ordinary metals and alloys can be welded. It is essential that the welder know the kind of metal he is to weld and any changes it might undergo both during and after the welding operation. In addition, the automotive repair man must have a comprehensive practical knowledge of welding. This knowledge can be acquired quite readily.

It will be my purpose to outline briefly some of the major applications of welding used in automobile repair work and to illustrate by examples of some of the jobs which we have been called upon to do.

Bronze-Welding

By means of bronze-welding, strong joints can be made in cast iron, malleable iron, steel, wrought iron, copper, brass, bronze and many other metals. In fact, practically all commercial metals except those which have melting points lower than that of the welding rod used can be bronze-welded. In automotive repair shops this process is used for repairing parts made of these metals and for building up worn surfaces.

The process of bronze-welding is based upon the fact that molten bronze will form a strong bond with metal surfaces which are clean and properly fluxed and which have been heated to the proper temperature. In bronze-welding metals having higher melting points than bronze, it is not necessary to melt the base metal. This means that the weld will progress more rapidly than it could if fusion of the base metal were required. In the case of castings it also means that welding can, with a few exceptions, be done without extensive preheating; so that frequently repairs can be made in place, which would otherwise require dismantling.

Many automotive parts are subject to considerable wear. When the tolerances for efficient performance of these parts have been exceeded, the worn surfaces can be quickly and economically rebuilt by means of bronze-welding, using special bronze welding rods that have been developed particularly for this work. Parts rebuilt with such rods will equal or exceed the normal life of the original part.

For building up worn surfaces on relatively small parts, the blowpipe flame can be used to heat the surface to the proper temperature. The surface is first carefully "tinned" and then the bronze is built up enough to allow for any subsequent machining that may be necessary. Holes that have become oversize are readily reclaimed by filling the hole with bronze and then redrilling to correct size.

Fig. 1—Burnt or Pitted Surfaces Rebuilt to Size by Bronze-Welding

Fig. 2—Cracked Water Pump Housing Repaired by Bronze-Welding

Fig. 3—Worn Bolt Hole in Shift Assembly Rebuilt by Bronze-Welding

Fig. 4—Cracked Timing Gear Housing Bronze-Welded and Ready for Replacement

A recent development that illustrates the procedure for building up more complicated parts is the bronze-welding of worn or burnt-out valve seats.

This work is being done on heavy-duty trucks and buses with great success and is an application that is profitable to everyone concerned as it frequently eliminates the necessity of purchasing a whole new cylinder block.

There are many other automotive parts that can be reclaimed with considerable saving by the bronze-welding process.

Some of the parts which are regularly reclaimed by bronze-welding include rear axle housing tubes, universal joint yokes, brake shafts, rear housing tubes, steering worms, universal joint yokes, motor supports, hoods, manifolds, cylinder blocks, crank cases, radiator shells, step boards, bumpers, accelerator pedals, brake pedals, etc.

Cracks in cylinder blocks are of several types. Perhaps the easiest to repair are cracks which occur in the water jacket in the head. In addition, cracks occur in the corners of the block, in the cylinder wall toward the center of the block, in the bottom part of the block and at times in the cast iron arms which appear on some makes of engine. For the latter type of break it is always necessary to take the block out of the car because, even though no preheating is done, it would be impossible to support the block in line when it is under stress.

The location of the break and the skill of the welder are the factors determining whether the cylinder block should be removed from the chassis for bronze-welding.

Bronze-welding is the only satisfactory method of repairing malleable castings, a variety of which is used in automotive work. The relatively low heat required in bronze-welding does not destroy the malleable properties. Transmission and rear axles housing are typical malleable iron parts.

Steel Welding

Certain sheet steel parts, such as bodies and fenders, are usually welded with a low-carbon steel welding rod.

Where welds of high quality and strength are required in steel, the use of a high-test steel welding rod is recommended.

The technique for welding steel with high-test steel welding rod is slightly different from the technique required for welding with a low-carbon steel welding rod.

Due to its deoxidizing and fluxing properties, high-test rod will unite with the sides of the vee ahead of the main part of the welding puddle as rapidly as the base metal has been brought up to the proper fusion temperature.

Cast Aluminum Welding

The automotive repair shop will encounter cast aluminum in such parts as crank cases.

Aluminum has several properties which must be understood by the welder. It conducts heat very rapidly and it has a low melting point, melting before it shows a red heat in daylight. It is also weak when hot, so that aluminum castings should always be supported in such a way that they will not collapse during preheating or welding. Molten aluminum oxidizes rapidly, the oxide forming a thick, heavy scum over the surface of the metal. Excess oxide may be removed during welding either by the use of a special flux or by scraping with a steel paddle or puddling rod formed by heating and flattening the end of a $^1/_4$-in. steel welding rod. Because aluminum castings tend to absorb oil and grease, it is always a good plan to heat the edges before welding in order to sweat out all oil and grease. Preheating has always been recommended to remove all possibility of cracking.

As experience in aluminum welding is gained, the welder will find that minor cracks and breaks in cast aluminum can be welded without the use of a preheating furnace. The necessary local preheating can be done with the blowpipe flame.

Sheet Aluminum Welding

When graded according to the necessary preparations for welding, sheet aluminum falls into three classifications: first, light sheet up to 0.050 in. This material is most easily welded by flanging the edges to be welded about $^1/_8$ in. These flanged edges are then fluxed, butted together and welded without the addition of welding rod. Second, aluminum sheet 0.050 in. to 0.125 in., which is best prepared for welding by what is known as "notching." These notches are about as deep as the thickness of the sheet and are spaced about $^1/_4$ in. apart. Notching is often accomplished by striking with a sharp edged tool. This notching insures full penetration, permits butting the sheets together during welding and decreases distortion because the notches act as expansion joints. Third, heavy material over 0.125 in., which is best prepared by beveling to form a 90 deg. vee. A shoulder or lip of about $^1/_8$ in. should be left at the bottom of the vee. This lip should be notched before welding.

Aluminum flux is used to dissolve and float to the surface all oxide either on or in the metal. Flux is best applied by mixing with water to a thin paste which, in the case of thin material, is applied directly to the metal to be welded and, in the case of thicker material, is applied to the rod before welding.

Lead Welding

Shops handling storage battery repairs find the oxy-acetylene blowpipe very useful in this work, as the operation known as "lead burning" is really lead welding.

Fig. 5—Fender Rip in Bus Body Repaired by Welding

The most important property of lead is its low melting point. A very small flame with a slight excess of acetylene is required.

Hold the blowpipe so that the flame is almost perpendicular to the surface of the work with the inner cone almost touching the metal. Heat the lead until it just melts, then lift the blowpipe quickly in order to prevent excess melting. In this way it is possible to control this easily fused metal.

The welding rod may be made by cutting sheet lead into strips, or by melting some lead and molding it into rods of convenient size.

In adding metal from the rod, the blowpipe flame should be played simultaneously on the rod and along the edges of the work to be welded so that they will reach the fusion point at the same time. Thorough fusion is just as essential in lead welding as it is in welding steel.

Storage battery repairs, "burning" plates to plate connectors, burning cell connectors or terminals to terminal posts and building up terminal posts, which have been drilled out when the battery was torn down, are some of the applications of bad welding the automobile repair shop encounters.

Soldering

Soldering work on feed lines, radiators and other small light sheet metal parts can be very efficiently carried out by using the blowpipe flame as a source of heat. Particularly on radiator work, it is almost impossible to reach certain parts with a soldering iron. The welding flame is ideally suited for such work. Other than this, soldering operations are carried out by the usual methods, substituting the flame for the iron. If a soldering iron is preferred for certain work, it can be rapidly heated to the proper temperature by the welding flame.

Another type of apparatus that has found particularly wide usage for automotive soldering work is the acetylene torch that gives a hot acetylene air flame. Soldering with this outfit may be done in two ways. Either the direct flame or a special soldering copper head that is heated by the flame can be used.

Heating

The welding blowpipe provides an ideal source of heat for localized heating. Such operations include straightening bent frames, rebabbitting bearings and heating dented body sections to restore them to their original shape.

For the straightening and repairing of frames, in addition to the welding outfit, four assisting tools are desirable. These are: a large monkey-wrench, about 24 in.; a pinch-bar; a sledge-hammer; and a hand-hammer. With this equipment it is possible to straighten any bent or torn frame.

With the largest size tip in the blowpipe, the flame should be first applied at the location of the greatest amount of bend. This section is brought quickly to a bright red heat, and then the frame is straightened as much as possible with a sledge-hammer and monkey-wrench. Further straightening is then carried out by reheating, applying a pinch-bar or straightening bar. Further reheating by means of the blowpipe with the use of a hand-hammer, and the sledge head as a "bucker," will then smooth up the wrinkles and give good alignment. Many other low-carbon steel parts can be straightened in the same manner.

The blowpipe flame offers ideal heat for the several operations necessary in the rebabbitting of worn-out bearings. It can be used to melt out the old babbitt, to clean the bearing mold of grease or other foreign matter, to heat the melting pot, to preheat the bearing block and to melt in the new babbitt metal. The easily controlled and concentrated heat of the blowpipe makes it possible to do this work quickly and with better results.

Hard Surfacing

The application of a wear-resisting alloy to certain wearing parts of buses and trucks such as clutch release yokes, clutch release housings and transmission shifters is a new development that promises to advance rapidly.

There are a few simple points which the welder should bear in mind in hard surfacing. The aim in hard-facing is to flow the alloy material over the surface of the base metal when the latter is at a sweating heat, spreading the deposit with the flame without stirring or agitating it with the welding rod. If this is properly done, a strong junction is secured without any noticeable degree of inter-alloying of the two metals.

An excess acetylene flame must be used. It is also necessary to see that no particles of scale are covered during the process. If these simple precautions are taken, any welder can, with a little practice, produce a good hard-facing job.

The use of the blowpipe for this work permits the heat to be carefully controlled. The abrasion-resisting alloy can be applied with an even surface and it is possible to work up fairly sharp edges or corners. This frequently reduces the amount of grinding necessary and cuts down the quantity of hard-surfacing material required for the work.

In general, the application will be advantageous on parts which are subjected to severe abrasive wear in locations where adequate lubrication is difficult. The majority of worn parts in lubricated positions can be satisfactorily built up by bronze-welding.

Body Repairs

In the field of automobile, truck or bus body repairs, use of welding has resulted in a notable reduction in time, labor and material costs. Replacement parts are not as often used and for the general run of vehicles a repair can be effected that will be completely invisible and will be as strong and substantial as the part was originally.

Alteration work has also been improved by the use of the blowpipe. In fact, a great many of the existing alterations and also those being carried out today have been materially reduced as to cost and time by having the blowpipe available for instant use.

In body repair work the blowpipe is used for three major operations: shrinking stretched or dented spots; welding tears or rips in the metal; and patching sections that are too badly damaged to be reclaimed.

Jigs and Fixtures

Every repairman knows which jobs he encounters most frequently. He knows that he will receive so many crank cases to repair, so many brackets to build up, so many spindles to be rebuilt by bronze-welding or other parts in which he is specializing, so that he will find it very profitable to prepare some type of apparatus which will hold such broken parts in an easy position for welding. This will greatly facilitate the work and permit of much faster operation. The welding and cutting blowpipes can, of course, be used to advantage in fabricating these work holding devices, and also many other handy items of shop equipment too numerous to mention here.

Discussion of Ernest Lunn's Paper, "Pre-Qualification Tests of Welders"

By H. E. ROCKEFELLER

✦Presented at the Fall Meeting of the American Welding Society in Buffalo, Oct. 5, 1932. Mr. Rockefeller is Development Engineer of The Linde Air Products Company.

MR. LUNN in his paper on the subject of "Pre-qualification Tests of Welders" has necessarily dealt rather broadly with this subject, because of its very inclusive scope. In discussing Mr. Lunn's paper, however, I am going to take the liberty of confining my remarks to a small but, to my mind, a rather important phase of the subject, namely, weld fracture tests and their interpretation.

Before getting into the discussion of this subject, however, and in order to indicate the value which I believe fracture tests may have in the pre-qualification of welders, let us consider for a moment the reason for making pre-qualification tests. Pre-qualification tests, of course, imply that subsequent and final qualification tests are to be employed for those applicants who successfully pass the initial or pre-qualification tests. It would appear, therefore, that the reason for making pre-qualification tests would be to eliminate as inexpensively and as rapidly as can logically be done those applicants who obviously could not qualify under the final qualification test requirements. Most final qualification tests which have been employed in codes and specifications to date have involved quantitative tests. These tests in turn have usually required accurate and rather expensive preparation of coupons for tensile and ductility testing. For example, in the requirements of the A. S. M. E. Unfired Pressure Vessel Code for Class 2 Welding, the cost of preparing and testing the samples required for the qualification of welders may amount to from $50 to $150 per operator tested, depending upon the thickness of material employed and whether or not test plates from two thicknesses of material are produced for each operator.

When employing such tests to qualify welders without some pre-qualification test, it is obvious that the expense of qualification can amount to a very considerable item, particularly where the ability of the average applicant for the particular work in question is low. This is often the case when a number of unproved men must be engaged in a comparatively short period of time. The expense of the final qualification tests is, therefore, probably the outstanding reason for the need of pre-qualification tests.

Time and facilities, however, are often also important factors in this connection. For the final qualification tests tensile testing machines are usually required and in a large percentage of shops such equipment is not available. This means that specimens prepared for tensile test must be sent out for testing. In a good many cases, furthermore, even the test plates must be sent out for preparation of the coupons. Besides involving a considerable expense, therefore, final qualification tests, if not preceded by a simple pre-qualification test, may cause an embarrassing delay in the development of the desired welding personnel.

Observation Test

The value of pre-qualification tests would appear to depend, therefore, on the relative cost and simplicity of such tests as compared with final qualification tests. The simplest and cheapest test undoubtedly is the observation test in which the welder's general ability is determined by mere observation of the manner in which he handles his equipment and deposits weld metal. Such a test, however, is only practicable where the individual supervising the observation is capable of properly interpreting what he sees. It is apparent, furthermore, that it is impracticable to attempt to describe to the inexperienced inspector what he should look for to enable him to pass, with any degree of accuracy, upon the ability of an applicant from a mere observation test. The observation test, therefore, is valuable only to well-organized shops supervised by capable welding foremen or welding engineers.

There are, however, literally thousands of concerns in the country today who have not developed or cannot logically afford to maintain welding supervisors capable of handling the pre-qualification of welders by a mere observation test.

Fracture Test

The fracture test, while slightly more expensive than the observation test, is considerably less expensive than any test involving preparation and testing of tensile coupons. Although it likewise depends upon the ability of the inspector to properly interpret the fractures, it is much easier for an inexperienced man to be trained in passing upon the ability of a welder from an examination of weld fractures than from mere observation of the welding as it is being produced.

The fracture test, furthermore, has much to recommend it in that it can be carried out very simply either in the shop or in the field, the only equipment necessary being an oxyacetylene cutting blowpipe to cut out the specimens from the test plate and a hammer and vise to produce the weld fractures.

Mr. Lunn under the heading of "Quality Tests" has described methods of producing the weld fractures both for butt welds and fillet welds. It will be my purpose, therefore, to attempt to indicate by a description of several illustrations of weld fractures the manner in which weld defects can be recognized and the fractures evaluated in terms of weld efficiency.

With the exception of the first fracture illustrated, which has been selected as representative of the minimum acceptable properties for qualification, the remainder of the fractures have been picked out as the worst possible cases illustrative of the defect under consideration. For the most part they have been taken from qualifying welds made by men professing to be welders but whose actual welding experience in reality was practically nil. It should not be presumed that these fractures are typical of welding as a whole.

The possible defects to be found in a weld are lack of penetration to such an extent as to include the side walls of the vee, laps or cold shuts in the body of the weld metal, slag inclusions and gas pockets. Their frequency of occurrence is in the same order, cases of insufficient penetration outnumbering the total of all

Fig. 1

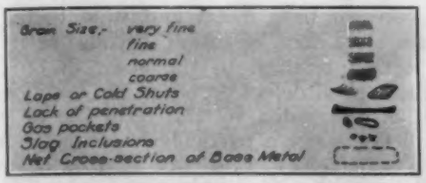
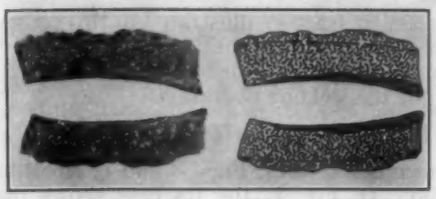


Fig. 2



other defects. All of the defects are due to lack of experience or incorrect practices or both.

To indicate the weld structure more clearly, line drawings have been made of each fracture showing the grain size, penetration, defects and net cross section. The legend used to indicate various properties of the fracture is shown in Fig. 1.

Description of Fracture, Fig. 2

The fracture illustrated in Fig. 2 is typical of what we should expect the average welder to do. The body of the weld metal shows a uniformly homogeneous structure, the fracture containing medium sized crystals evenly distributed. This structure extends the full depth and width of the welded area with the exception of a narrow section at each edge where grain refinement has taken place due to the heat of the cutting blowpipe. This fine grained area is denoted on the line drawing by small dots. Blowpipe-cut coupons will invariably exhibit this structure and occasionally the fractured surface will show a shear type of failure at the edges. This type of failure is a normal occurrence and is not due to defective weld metal.

The cross-hatched area denotes the zone of lack of penetration at the bottom of the vee. This zone should be noted, particularly with respect to its extent, and its area compared with that of the sound weld metal.

In the present illustration the coupon falls within the specification "penetration to and including the unbeveled portion" and is acceptable from the viewpoint of fracture examination for a single vee weld. This particular coupon, furthermore, had an acceptable amount of reinforcement, good contour and bent through 80 deg. before fracture occurred, showing ductility to be up to requirements. Hence, the weld was accepted as fulfilling the minimum requirements.

Description of Fracture, Fig. 3

The crystal structure shown by the fracture in Fig. 3 is uniformly good. Penetration of the weld metal, however, is not sufficient to meet the minimum requirements and the coupon would have to be rejected. Also it should be noted that the amount of reinforcement is insufficient.

This coupon is illustrative of the most common defect in single vee welding, i.e., lack of penetration which is of sufficient extent to include not only the bottom of the vee but the side walls as well. The two humps in the cross-hatched area represent portions of the side wall of the base metal to which fusion was not obtained. Naturally this is an undesirable condition and condemns the coupon from further consideration.

Slag inclusions are of relatively infrequent occurrence. This is particularly true when high-test rod is used, since the self-fluxing property of the rod acts to clean the weld metal of all impurities. This coupon contains three slag inclusions, denoted by the solid black patches, two near the top surface of the weld and one adjacent to the side wall near the unfused area.

Fig. 3

Lack of penetration which includes the side walls is caused by allowing the molten puddle of weld metal to flow into the vee before the base material has reached a fusion temperature. The result is adhesion instead of fusion. The remedy, obviously, is to bring the base metal to the proper temperature before adding any welding rod.

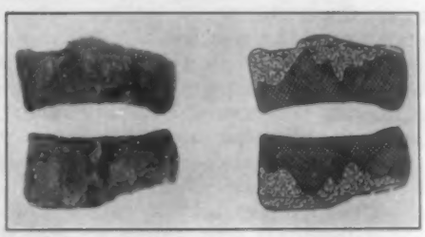
Slag inclusions usually are due to the characteristic some welders have of carrying too small a puddle of molten metal, so that the puddle solidifies before the inclusions have an opportunity to work their way to the surface.

Description of Fractures, Figs. 4 and 5

A lack of penetration which is of sufficient extent to include the side walls of the vee for any appreciable area is a very serious fault. Such a weld is signally lacking in strength, particularly when subjected to vi-

Fig. 4

Fig. 5



brational or impact stresses. The fractured coupons, shown in Figs. 4 and 5, amply illustrate this defect. Both welds are worthless.

An examination of the photographs will show that where fusion was not obtained to the side walls, marks left by the cutting blowpipe in beveling the pipe are plainly discernible. Weld metal was placed in the vee without apparently any attempt being made to fuse the base material. The welding rod was "smeared" in, leaving nothing more than a superficial weld junction of welding rod to base metal on the top surface of the weld.

Protrusions of weld metal beyond the bottom of the vee in Fig. 4 should be noted. This is considerably in excess of that allowable and in this particular coupon

was probably caused by an irregularity in the blowpipe cut bevel forming a hole through which the molten puddle ran. Large protrusions of this nature denote lack of experience on the part of the welder.

Both these illustrations are of coupons taken from a rolling weld. On the basis of the fractures, the welder naturally would be rejected from further consideration. His low penetration is due to insufficient heat upon the sides and bottom of the vee.

Occasionally, coupons taken from welds made in a vertical position will show a similar fracture. There will be lack of fusion to one side wall but the base metal upon examination will show a bright metallic luster instead of the dark oxidized appearance of the above illustrations. This is caused by an unequal distribution of heat to both sides of the vee, the probability being that the unfractured side is properly fused. The metallic luster of the unfused side shows that the base metal was heated sufficiently to melt the oxide film but not enough to secure the desired fusion.

Description of Fracture, Fig. 6

This coupon was taken from a vertical fixed position weld and presents several interesting features. There is no zone showing lack of penetration; the welder fused through the complete thickness of the pipe wall, but in doing so, he neglected to add sufficient metal so that, instead of having weld reinforcement, the fractured area is actually less than the net cross-sectional area

Fig. 6

of the pipe material being welded. The fracture for the most part is composed of a fine, silky-grained structure with two or three areas of slightly larger grains. The largest grains, however, are considerably smaller than the normal weld structure. Compare this illustration with Fig. 2. Furthermore, although the grain structure is fine, the fracture is rough and irregular and three small laps are discernible.

The coupon would be rejected.

A fine-grained structure in welding is due to a reheating operation. If we take a coupon in the "as-welded" condition, having the normal structure of Fig. 2, and reheat it with the blowpipe or other means as the temperature of the weld metal rises, a temperature is reached at which there is complete re-orientation of the crystal structure. This temperature is called the "critical point' and, if from this temperature we cool the specimen and fracture it, it will be found to be extremely fine grained and silky-like in appearance.

The fine grain of this particular fracture was produced by just such a process. The welder was not adept at welding in a vertical position; he was afraid that the weld metal, if carried in a puddle form, would drop out, so he welded with a small flame, barely brought the surface of the base metal to a fusion temperature, added a small amount of welding rod and then removed his blowpipe to allow the added metal to solidify before progressing further. Thus, the previously added metal was heated and reheated and its grain structure refined.

Presence of laps or "cold-shuts" was due to the method of welding. Wherever a lap occurs, it signifies that weld metal was added before the adjacent metal was brought to the correct fusion temperature. A lap occurring between base metal and weld metal is given a separate term, lack of fusion, because of its position and important relation to the strength of the joint. When this type of defect occurs in the body of the weld metal, it is designated by the term lap or cold-shut.

A small lap is not a particularly serious defect in an otherwise satisfactory weld, but it does denote faulty technique.

The irregular fracture illustrated in this coupon would have been overcome if the welder had used a larger flame and had carried a definite, if small sized, puddle throughout the welding operation.

Description of Fracture, Fig. 7

In previous fractures, Figs. 3 and 6, small laps were illustrated. In Fig. 7, the fracture shows the extent to which laps may occur when a welder is inexperienced.

Fig. 7

This coupon was taken from the finish of a weld made in a horizontal fixed position. Particular note should be taken of the grain structure. The right-hand half of the coupon is composed of very fine grains. The left-hand half contains the normal "as-welded" structure. During the welding of the pipe joint, the right-hand half of the joint was welded first, since in horizontal position welding the weld would be started at the bottom and carried up one side to the top. Welding would then be started again at the bottom, carried up to the opposite side and tied in to the part first welded. As the second half of the weld nears completion, the heat of the welding operation reheats the part first welded. This reheating causes the grain refinement illustrated. The normal structure to the left is that portion of the coupon last welded.

The large laps were caused by the deposition of welding rod before the metal beneath was up to a fusion temperature. This is entirely attributable to negligence on the part of the operator in failing to follow accepted practices in sealing off the terminus of the weld, whereby the part first welded should be remelted nearly to the bottom of the vee for a distance of about 1 in., after which welding rod is added to complete the weld.

Description of Fracture, Fig. 8

On relatively infrequent occasions, blowholes or gas pockets will be found in the body of the weld metal. Fig. 8 illustrates a weld which was a particularly bad

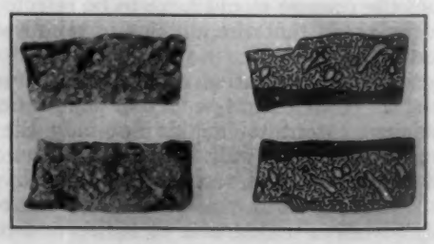


Fig. 8

offender in this respect, the extent and distribution of blowholes being such as seriously to impair the strength

of the joint. A blowhole is a non-permissible defect. The requirements for qualification are based upon defect-free weld metal, hence the presence of a blowhole is justification for rejecting the coupon.

Aside from the blowholes, the fracture shows insufficient penetration and a small lap in the lower left-hand corner. Furthermore, fracture occurred when the coupon had bent through an angle of less than 10 deg. Any single one of these properties would cause the coupon to be rejected.

Blowholes are caused by the generation of gas in the molten puddle, the gas being trapped as the metal solidifies. Dirty base metal and particles of slag are particularly prone to generate gas, but in a correctly executed weld this gas is released before the weld metal freezes. In the fracture illustrated, probably both of these circumstances were contributing factors, but by a proper welding technique they could have been nullified. This particular weld was carried forward too rapidly, whereby the welder, although securing fusion to the side walls of the vee, did not put enough heat into the base metal to retard the solidification of the puddle until the entrapped gas had escaped.

The remedy lies in using base metal of suitable welding quality, properly prepared, and in carrying forward the welding operation at the correct speed.

Bronze Welding in Locomotive Maintenance and Repair

By W. S. FARR

†Paper presented at Sept. 20, 1932 Meeting, New York Section, American Welding Society, by W. S. Farr of the Applied Engineering Department, Air Reduction Sales Company.

THE material contained in this paper applies to the application of bronze welding locomotive frames, cylinders, building up worn pistons and tinning driving-boxes for bonding crown brasses, taken from reports of our field servicemen.

Bronze welding of broken locomotive frames is displacing welding with steel rods on some railroads. Its use has been uniformly successful where properly applied. The decrease in time required to make a bronze weld has been an important factor in its adoption. This is true especially when frame breaks occur in power needed to carry on the railroad schedules.

There are two reasons for the saving in time when using bronze welding. The base metal is not melted and consequently the rate of welding is faster than when a puddle weld is used. Neither is it usually necessary to strip the frame near the break, whereas in similar locations complete stripping might be required to obtain the proper contraction allowance and access to the break, if welded with steel rods.

When the frame is trammed and the calculation for contraction allowance made, only a little more than half that required for puddle welding will be found necessary. The area around the bronze weld is not raised to such a high temperature and hence the expansion is not so great. Three-sixteenths of an inch should be sufficient for the top and bottom rails with about one-eighth inch for the pedestals.

Fig. 1—Locomotive Frame Jacked Apart at Break to Provide for Contraction of the Weld

Fig. 2—Locomotive Frame Shown in Fig. 1 after Welding

The preparation of the break in the frame is practically the same as for puddle welding. A double vee is made in heavy sections, using an oxyacetylene cutting torch to cut out the break. A sand-blast is used for cleaning up the vee before bronze welding. The sand-blast removes all the scale and foreign matter and leaves the surface chemically clean to take the bronze.

The spacing of the frame should be obtained with the use of heavy steel jacks. Wood blocks are to be avoided as they are likely to give a little. In places where the contraction allowance is hard to get, it is all the more important that it be had at that point to insure a satisfactory job.

The bronze welding, like steel welding, is done with two operators, one on each side of the double vee. In this way, the operation can be completed more quickly and with fewer man-hours than if one operator was used. The heat from one torch helps the other, making it possible to increase the rate of welding.

The frame in Fig. 1 has been prepared for welding by veeing out the break. The jacks are shown holding the top rail apart to make the proper contraction allowance. The spacing shown in this illustration is far more than is required for bronze welding. A bad section of metal was encountered in this break and had to be removed. A new piece of steel the proper size was fitted into this space and the welds made on each side of the piece. Two complete welds were made in place of the one usually necessary in such cases. The welds completed are shown in Fig. 2.

The cost of bronze welding is about the same as puddle welding, using a steel rod of approximately the same analysis as the frame. The cost of Tobin bronze or other bronze used is higher than the steel rod. The reduced labor and gas costs offset the higher rod costs. The operators prefer bronze welding as less heat is required. The operator's preference for bronze welding, the appreciable saving in time over the former method at no additional cost and the satisfactory results obtained have all combined to win its acceptance.

The data in Table 1 show the bronze rod, gas consumptions and labor requirements for typical bronze welding jobs on locomotive frames. The break in the first frame was in such a position that the veeing and welding all had to be done from inside of frame and under cylinders. If the weld had been impossible to make in position, the engine would have been tied up for a week or ten days to have the cylinder removed

Fig. 4—Logging Locomotive Cylinder Frame Casting Bronze Welded

Fig. 3—Logging Locomotive with Broken Cylinder Frame Casting

and the frame welded. The other frames were welded from both sides and in less difficult places.

A comparison between the cost of bronze welding and steel welding the same size locomotive frame is given in Table 2. The difference in cost is about 12½ per cent in favor of bronze welding. In the majority of cases, the cost will run about the same for the two methods on frames of equal size. The saving in time gives bronze welding the advantage.

The locomotive shown in Fig. 3 is a type used in hauling logs over rough country. The cast frame cracked just behind the main drive shaft bearing. Fig. 4 shows the break after welding. The work was accomplished from the outside. The bronze welding was carried on with two torches. The cast iron was preheated first and then the actual welding was done. The two torches were used, one ahead of the other. The first torch filled the bottom of the vee, and the second, working as close to it as practicable, filled the remainder of the vee and added the reinforcement. The welding cost about $50 and a new casting would have cost about $1200 installed, besides the loss of the service of the locomotive while awaiting the casting.

Table 1—Bronze and Rod Gas Consumption Heavy Locomotive Frames

Frame Size	Man-Hours	Rod Wt., Lb.	Oxygen, Cu. Ft.	Acetylene, Cu. Ft.	Flux, Wt. Lb.
6 x 12	12*	110	830	820	–
6½ x 15	10	163	860	850	3
7 x 16	10	135	800	760	2

Cu. Ft. Ox. per Lb. Rod	Cu. Ft. Acet. per Lb. Rod	Lb. Rod per Man-Hour
7.55	7.45	18.3
5.27	5.22	16.3
5.92	5.63	13.5

* One torch welding and one heating.

Table 2—Comparison Bronze Welding Rod and Steel Welding Rod

Bronze Welding Rod

Material	Quantity	Unit Cost	Total Cost
Acetylene, Cu. Ft.	132	$0.025*	$ 3.30
Oxygen, Cu. Ft.	139	0.0125*	1.74
Labor, Hours, two men	2	1.60*	3.20
Tobin Bronze Rod, Lb.	8	0.28	2.24
Flux	...	....	.25
			$10.73

Steel Welding Rod

Material	Quantity	Unit Cost	Total Cost
Acetylene, Cu. Ft.	165	$0.025*	$ 4.13
Oxygen, Cu. Ft.	176	0.0125*	2.20
Labor, Hours, two men	2.5	1.60*	4.00
Vanadium Steel Rod, Lb.	8	0.22	1.76
			$12.09

* Based on oxygen $1.25, acetylene $2.50 and labor at $0.80.

Cylinder Welding

The bronze welding of locomotive cylinders is a little more difficult in many cases than the frames. The sections are not as heavy but frequently there are pieces broken out or lost that must be replaced. The proper fitting-up of the parts before welding is important, as the proper alignment before welding will often save machine work afterward.

Cast iron welds in locomotive cylinders are more difficult to make than bronze welds. Bronze welding is comparatively simple. The metal around the break after veeing with torch is cleaned out well, either by grinding or chipping. Sand-blasting makes the best cleaning agent when one is obtainable. Old front end screening is placed in the valve chambers and cylinder for a grating. The valve chambers and cylinder are filled with charcoal and then wrapped in roll asbestos to keep the heat in. Some provision must be made to allow the air to circulate through the charcoal to keep it burning.

Thus, the cylinder does not have to be preheated

Fig. 5—Locomotive Cylinder with Badly Broken Barrel

Fig. 6—Locomotive Cylinder Shown in Fig. 5 with New Barrel Section Bronze Welded

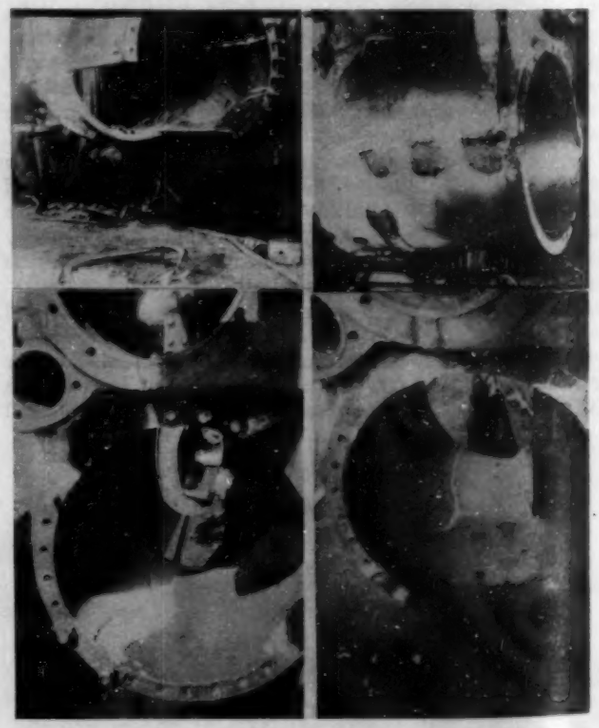


Fig. 7—Locomotive Cylinder Veed in Crack for Bronze Welding

Fig. 8—Locomotive Cylinder Shown in Fig. 7 Bronze Welded

nearly as much usually, as when welding with cast iron rods. When the cylinder is ready for welding, the asbestos is cut along the line of the break. The operator can then work through the asbestos and at the same time be protected from the heat of the charcoal. After the welding is completed, the holes in the asbestos are covered and the cylinder allowed to cool slowly.

The cylinder shown in Fig. 5 has been prepared for welding. It was so badly damaged that a new piece had to be cast to replace the section that was broken out. The piston head nut worked loose and dropped between the cylinder head and the piston. The new piece was 27 in. long, 28 in. wide and 2 in. thick.

The finished job is shown in Fig. 6. Nearly all the bronze welding was done overhead which added to the difficulty. The cylinder was preheated before welding. The total cost of repairs, including the foundry and welding charges, was $154.

A new cylinder would have cost about $1700 and replacing on the locomotive about $1000 additional. The saving in cost of labor and material due to welding was over $2500. In addition to this saving, a new cylinder would have necessitated tying up the locomotive for several weeks.

A cylinder which was broken when a combination lever failed while the locomotive was running at 40 miles an hour is shown in Fig. 7. An excessive steam pressure was built up and blew out part of the steam ports and cracked the cylinder. The cracks and breaks are shown prepared for welding. The missing pieces of the steam ports were replaced with forgings made of tire steel machined to the proper shape.

Old front end screening was placed in the valve chamber and main cylinder to form grates for the charcoal. Charcoal was used for heating and the whole cylinder wrapped in asbestos paper.

The welding was done by the operators in the railroad shop and the finished cylinder is shown in Fig. 8.

The following material was used on the work: oxygen 1300 cu. ft.; acetylene, 1300 cu. ft.; 1/4-in. Tobin bronze, 120 lb.; flux, 2 lb.; charcoal, 400 lb.; 15-lb. roll asbestos; and approximately 14 man-hours. The work was completed satisfactorily, and the locomotive returned to service shortly thereafter.

Building Up Worn Pistons

The bronzes used in welding locomotive frames and cylinders was Tobin or some other of similar characteristics. The principal requirements are that the bronze be ductile and of good tensile strength. The question of wearing quality does not enter the picture.

The bronze used for building up wearing surfaces must be harder to stand the abrasion to which the moving parts are subjected. Manganese bronze has been found to meet these wearing conditions very well as it has an unusual resistance to wear.

Locomotive pistons wear on the lower half of the circumference where their weight rests on the cylinder. After a long period of service this amount of wear becomes appreciable. If allowed to continue, the rings will work out of the grooves on the top of the piston and allow steam to leak badly. The former practice, before the advent of building up with manganese bronze was to re-bore the cylinder and if necessary re-bush it also. A new piston, of course, was necessary to fit the new diameter cylinder.

The present practice is to put manganese bronze on the worn portion of the piston. Where the piston is worn badly the manganese bronze is put all the way around, building up the lands on the piston to the desired diameter. The piston is then turned to the proper size in a lathe.

Bronze Welding Driving-Box Brasses

The crown brass bearings in locomotive driving-boxes are subjected to severe operating conditions. Heavy loads, high unit pressures, high axle rubbing speeds, road shocks and the fore-and-aft thrusts of the pistons help to make crown brass repairs to locomotives one of the chief items of locomotive maintenance. The replacing of crown brasses is expensive as the wheels must be dropped with the necessary disconnecting of driving rods, removal of frame binders, wedges, shoes and replacement of them.

The brasses are machined to a crescent shape with the toes of the crescent cut off just below the center line of the inner circle. The brass is pressed into a machined seat in the driving-box conforming to the outer circle and the toes of the crescent.

The heat generated by friction and the shocks and jars received while operating loosen the crown brasses in their driving-box seats. Destructive pounding follows this and repairs must be made immediately. With the exception of bronze welding, none of the methods tried to hold the crown brass firmly in the driving-box has been successful.

A method of fastening the crown brass to the driving-box has been developed by one of the railroads in co-operation with our Company. The driving-box is covered with Tobin bronze or other similar bronze on the surface where the crown brass fits, to a depth of 1/8 to 1/4 in., using an oxyacetylene welding torch. The bronze is applied just the same as in bronze welding. A sand mold to give the desired shape in the finished crown brass is placed in the driving-box. The driving-box is then heated to a temperature just below the melting point of the bronze. The bearing brass is then poured in and fused to the bronze welded to the driving-box. A solid bond between the driving-box and the crown brass is thus obtained. The crown brass is then machined to fit the axle bearing.

This method of fastening the crown brass in place has the advantage of holding it permanently in place and also making the driving-box act as a better radiator of heat from the crown brass. A slight air space between the crown brass and driving-box acts as an insulator, but with a solid metal bond between the parts, the heat conductivity is increased and the operating temperature of the crown brass is reduced.

These applications of bronze welding do not cover completely its use in locomotive maintenance and repair work. They have been selected, however, as those in most general use on railroads throughout the country.

Structural Steel Report

This book of over 200 pages, summarizing the results of tests of thousands of specimens, has been placed on sale for a short time at $0.50. Place orders with the Secretary.

Welded Joints for Seismic Stresses in a Tall Building

By H. H. TRACY

✦Mr. Tracy is Structural Engineer, Southern California Edison Co., Ltd.

Comment by Editor Engineering News-Record:

The following article is a brief of a paper that was awarded third prize in the second arc welding prize competition sponsored by the Lincoln Electric Co., Cleveland, Ohio. An important feature of welded joints in structural steel assemblages is that they may be made more compact than riveted joints of equal capacity. Welded joints in general can also be made more rigid than riveted joints. Advantage of these two characteristics of welded joints was taken in the design of the thirteen-story office building of the Southern California Edison Co. in Los Angeles, when it was determined to proportion the structure to resist earthquake forces as well as dead, live and wind loads. The author's enthusiasm for welding is obvious, so that the comparative figures of weights and costs of welded and riveted designs are probably as favorable to welding as they can be. Nevertheless, the data given should command study and attention, for they concern a problem that will recur as tall buildings are built in locations where lateral forces, whether from earthquake or wind, are important.

THE seismic design of the new office building of the Southern California Edison Co., in Los Angeles, presented structural problems of unprecedented character. Although several buildings in Japan had been designed to resist seismic stresses, they were not more than six stories in height and therefore not comparable to the thirteen-story Edison building. The riveted construction of these Japanese buildings required large members and cumbersome connections. By the application of arc welding the seismic design of the Edison building was not only successfully accomplished, but the resulting steel frame with its rigid connections and bracing was but slightly heavier and very little more cumbersome than would have been the case had the standard riveted design been used, with the resulting relatively flexible frame.

Fig. 1—The steel frame of this thirteen-story building was designed to resist earthquake forces, welded joints being used. Riveted connections, as required by the building code, carry the vertical live and dead loads

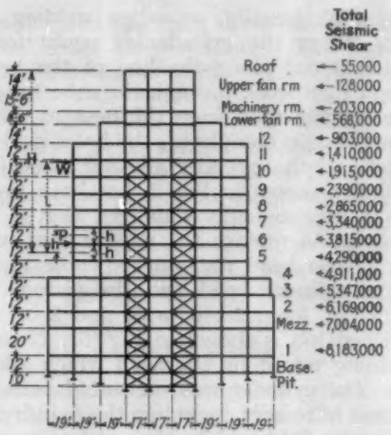


Fig. 2—Seismic Shears for Each Floor Used in the Design of the Southern California Edison Co. Building in Los Angeles

At the time that the design of this building was carried out, the building code of the city of Los Angeles did not permit dead or live floor or roof loads to be supported by welded connections. For this reason it was necessary to use riveted beam-to-column connections and riveted column splices, in addition to the welded seismic connections. As the welded beam-to-column moment connections were much stronger than these riveted connections, practically all of the rivets used in the building could have been omitted without in any way impairing the strength of the structure. Moreover, due to the inevitable flexibility of riveted connections, it would be necessary for the welded connection to fail before any appreciable load would be taken by the riveted connection.

The total seismic shear at each floor is shown on Fig. 2 and is based upon Newton's law. These shears were resisted by two general types of design: interior rigid frames formed by welded beam-to-column connections and framed portals located in exterior walls and solid interior walls.

A typical welded beam-to-column connection is shown in Fig. 3. The simplicity of this connection is evident, particularly in view of the fact that it develops the full strength of the beam. The plates connecting the beams to the column webs also serve as continuity plates to transmit stresses between column-flange beam-connection plates. The lower plate in the web connection was shop welded, reducing field overhead welding to a minimum. In the heavier connections in the lower floors of the building the small 1-in. triangular plate was used to provide a means for obtaining sufficient weld. As this plate is on the center of the column, the stress transmitted by it goes directly through the column web, thus avoiding excessive stresses in continuity plates. The standard web connection shown is the riveted connection required by the building code to carry dead and live floor loads. Due to the relative flexibility of this type of connection, a special design had to be adopted to assure the load being carried by the riveted connection and not by the welded seismic connection. Referring to Fig. 3, the lower welded connection plate is located $^1/_8$ in. below the beam flange, and the welding between the plate and beam is terminated 4 in. from the column flange. The welding on the top plate is also terminated some distance from the column, so that when the load is applied to the

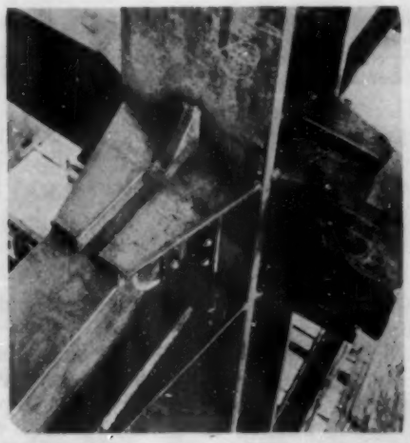


Fig. 3—Typical Welded Beam-to-Column Connection in Southern California Edison Building. The riveted web connection shown is required by the Building Code

beam it may drop sufficiently to cause the riveted connection to absorb the load.

The horizontal forces that portal frames (K-braces) were required to resist range as high as 332,000 lb. on the lower floors. The magnitude of the stresses in the members of this portal indicate the difficulties that would have been encountered in attempting riveted design. In the case of most of the web members sufficient room between chords was not available for the placing of the required number of rivets. In the case of the kneebraces, gusset plates of such a size would have been required as to encroach upon window openings. In addition to these difficulties, practically all members would have had to be increased materially to maintain net sections, due to rivet-hole deductions.

Even with the welded design, it was necessary in many cases on the lower floors to use plate girders instead of framed portals. For many of the plate girders moment connections to columns were required, which it would have been impossible in the room available to design for the use of rivets. Moments in excess of 600,000 ft. lb. were developed by the use of more than 80 lin. in. of $^{3}/_{8}$-in. fillet weld.

The large column direct stresses induced by seismic forces required that coverplates be used on certain interior columns at the lower floors. These columns were 16-in. x 363-lb. H-sections, and one 18 x $1^{1}/_{8}$-in. coverplate was applied to each flange. Riveted fabrication for these members would have necessitated drilling the $2^{7}/_{16}$-in. flange of the columns, but with welding this slow and expensive operation was eliminated.

The actual weight of the welded steel frame and the estimated weight of a standard non-seismic riveted design may be compared as follows:

	Welded Seismic Design, Tons	Riveted Non-Seismic Design, Tons
Columns	1387	1318
Column connections	248	235
Grillage	27	27
Base slabs	140	133
Beams	1019	917
Beam connections	192	64
Portal trusses (also serve as spandrel beams)	524	262
Total	3537	2956

The riveted steel frame of the building was furnished and erected at a price per ton of $96.50, and all welding was done at an additional cost on a time and material basis.

Cost per ton, not including welding	$341,320.00	$96.50
Cost of welding, per ton	80,290.00	22.70
Total cost per ton	$421,610.00	$119.20

The cost of the standard non-seismic riveted design at $100 per ton would have been $295,600, so that the increase in cost due to welded seismic design was $126,010 or 42.6 per cent. It is pertinent to point out that this increase in cost is excessive by the amount of the cost of unnecessary connections imposed by the building code. The actual ton price of steel with welded construction should be no more than with riveted construction. Assuming, as above, that this price is $100 per ton, the cost of the arc-welded seismic design should be 3537 x 100, or $353,700, which is $58,100, or 19.7 per cent more than the cost of the non-seismic riveted design.

The following estimates have been prepared to compare the weight and cost of a riveted frame designed for the same conditions as an arc-welded frame. It should be noted at the same time that many features necessary for a satisfactory seismic design of a building of this height would be exceedingly difficult and in some cases practically impossible to obtain without arc welding.

A comparison of the costs of welded and riveted designs follows:

	Tons	Cost per Ton	Total Cost	Per Cent Increase
Non-seismic riveted design	2956	$100	$295,600	..
Welded seismic design	3537	100	353,700	..
Riveted seismic design	4481	100	448,100	..
Increase—welded seismic over riveted non-seismic design	581	100	58,100	19.6
Increase—riveted seismic over riveted non-seismic design	1525	100	152,500	51.6
Increase—riveted seismic over welded seismic design	944	100	94,400	26.7

In addition to these direct savings, there is a considerable floor area made available by using a welded design. For the entire building this would amount to about 6300 sq. ft. As a building is erected primarily for the purpose of providing floor space and as this building cost about $15 per square foot, the welded design caused a saving in floor area of $15 × 6300 or $94,500.

Weight Comparison of Beams, Trusses and Connections for Welded and Riveted Seismic Designs

Beam	Welded Seismic Design, Tons	Riveted Seismic Design, Tons	Increase Riveted Over Welded, Tons	Cost of Increase Riveted Over Welded
Connections	192	801	609	$60,900
Beams	1019	1223	204	20,400
Trusses	524	655	131	13,100
Total increase			944	$94,400

No addition to column steel is assumed, although column net sections to resist bending would be considerably reduced by riveted connections.

The total savings made possible by an arc-welded seismic design over a riveted seismic design may be summed up as follows:

Direct saving in steel tonnage	$94,400
Indirect saving in floor area	94,500

A direct comparison of the costs of welded and riveted seismic designs is as follows:

Increase in cost of welded seismic design over riveted non-seismic design	$ 58,100
Increase in cost of riveted seismic design over riveted non-seismic design, including indirect costs	247,000

The increase in cost due to seismic design would, in the case of riveted construction, be 2.62 times that of welded construction, providing only direct costs were considered, and 4.25 times the welded cost if indirect costs were included.

Consumer Acceptance: The Welding Industry's Greatest Problem

By T. C. FETHERSTON

†This paper was presented at the Fall Meeting of the American Welding Society in Buffalo, Oct. 5, 1932. Mr. T. C. Fetherston is Manager of the Technical Publicity Department of The Linde Air Products Company.

IF WE were to seek one point of interest significant to everyone who attends this meeting in whatever capacity, we would find it probably in a basic interest in selling. Just as truly as those who are in Buffalo today seeking orders for welding and cutting supplies and equipment or working to sell welded products, every engineer, every research worker, every welding operator, interested in the subject of welding by whatever process and to whatever degree, is or should be exerting some measure of effort to sell the welding process to industry.

Let us consider, as a means of approaching the subject, just what selling involves.

In the first place, in order to sell successfully any product, process or even idea, there must be a demand for it—actual or potential—or a situation existing whereby a demand can be created. Otherwise, there must be already in existence a product or process, or several of them, over which the new idea has inherent, economic or other advantages. No product, no idea, however superficially attractive, can be merchandised over a period of time, if it does not have real merit from the standpoint of the user. New ideas cannot be successfully promoted against the economic trend; and you may well be assured that today even more definitely than in other times, a product, a process or an idea that will not stand searching and analytical scrutiny has little chance of ultimate success. Assuming, then, a product or process which is economically sound and for which some market may exist, we may set up for ourselves as an objective, the matter of convincing logical consumers that they should use our products or utilize products that are made through the application of our process.

It is easy to phrase in the abstract the familiar sequence used in planning a marketing program. The theory is that one should determine where the market exists, what motivating influences must be set at work to capture this market, and then translate these latter by all the methods known to sales promotion people into an urge to buy the product. But let us be concrete and discuss particularly the welding industry and the welding process.

In the first place, let us make it clear that we are talking now about *welding;* not about arc-welding, thermit-welding, gas-welding or any other type of welding, but about welding as a basic process of joining metals. It is possibly true that the welding industry would be at least five years in advance of its present position today if the public—which cares not a bit about fine technical distinctions—had from the beginning been approached with the thought that welding, as a basic all-inclusive process, deserved technical and practical consideration.

As it is today, the situation reminds us of the man who recently considered buying an oil burner. He studied the rotary types and the pressure types and the pot types. The proponent of each had dire things to say about the others. Claims were confusing—contradictory. This man studied the problem, listened to the salesmen and the engineers for weeks, and finally bought not a rotary type, nor gun type nor pot type oil burner, but 17 tons of coal.

Welding has a real place in American industry. In maintenance and reclamation work alone there are reliable statistics to show that by a single process of welding approximately $500,000,000 a year is saved in the replacement value of machinery. This does not take into consideration any losses in production time, nor the economic value of destroyed purchasing power through lost labor time. Projected to cover all processes of welding there is substantial reason to believe that nearly $1,000,000,000 per year is saved in this way. The indications are, further, that under today's conditions welding is more important from the standpoint of plant maintenance and rehabilitation than it ever been has in the history of American industry.

From a production and construction point of view the place of welding in engineering and industry is just as well defined. This process makes possible better, more efficient products and reduces their production cost. These products range from 1000-mile gas pipelines and multi-storied buildings to steel belt buckles or platinum rings. The technical acceptance of welding from this point of view has been especially gratifying since, in the main, considerations of quality in the finished product or efficiency of production methods have been determining factors, rather than the matter of reduced costs alone.

In general, engineers know these things. Those who do not are learning day by day the value of welding in their particular phase of the engineering profession through the only means by which a process can be sold to engineers; that is, by demonstration of practicability and reliability. More rapidly than ever before, this phase of welding's selling program is going forward.

The man in the street, however, the average citizen, the buyer of cars and lawn mowers and washing machines, the owner and builder of the small home, the apartment house owner, the workman in the plant,

the shopkeeper and the holder of political office do not know about welding. The welding industry has been much less than completely successful in one of its most important jobs. It has not sold the public on welding.

If you went out in the street in Buffalo this morning and asked the first passerby you met something about welding, he would undoubtedly look at you in a blank sort of way and say, "Oh yes, I saw a man doing that the other day on the trolley track!" This seems to be the extent of the average citizen's idea about welding; and you will find as often as not that the man working on the trolley track was not welding at all, but was cutting. And welding, with respect to its important commercial applications, is just about twenty-five years old this month.

Consider now for a moment a technical development which is not more than five or six years old—that of the so-called stainless steels. For various reasons, some of which you will think of immediately, the mention of stainless steel leaves a definite idea in the mind of the average individual. You will argue probably that this idea may not be an exactly correct one, but that is of little importance. It is enough to recognize the fact—and it is a fact—that mention of the term "stainless steel" will picture in the layman's mind some especially excellent type of steel that will stay sharp for a long time if made into a kitchen knife, and will not discolor if the user neglects to rinse it after cutting a lemon. In Woolworth's, the index of acceptance for the city dweller, and in the Sears-Roebuck catalog—the bible of agricultural thought on many things—you will find as an advertised feature, "This article is made of Stainless Steel."

This consumer acceptance (for that is exactly what it is) is being reflected every day in an extension of the uses of alloy steels into many hundreds of technical and domestic applications. Acceptance of "stainless steel" as a household term, to cover a wide range of alloy steels, has carried with it expanding business for makers of chrome-nickel steels, cromansil steels and many other types of corrosion-resisting alloys.

In the welding field the efforts which have been made by manufacturers of welding equipment and supplies to promote the acceptance of welding as a process, and of welded products, are familiar, undoubtedly, to all of you. Some of the larger manufacturers have devoted a major percentage of their advertising appropriations to the promotion of the process rather than the promotion of their own products. This is not, of course, entirely altruistic; such efforts would necessarily have to be justified by the increasing sale of the products of these companies. It is significant, however, to note that ten or a dozen companies have carried over the years the burden of the active promotion of the welding industry.

A survey recently made covering a number of industrial and class publications with respect to welding advertising indicates that over the last three years 65 different firms advertised welding equipment and supplies or advertised that their products were made by welding. Of this group, 56 were welding equipment and supplies manufacturers, and only 9 were manufacturers of welded products. It is difficult to estimate how many concerns in the country are producing welded products, but it is safe to say that the total is many times as great as the number of supplies and equipment manufacturers. Each one of these companies should seriously consider the marketing advantage given its products by welding.

Such manufacturers might question themselves on why they accepted welding as a production process. The answer may sometimes be that the products could be more cheaply produced by this means, but usually this is not the sole reason for the use of welding. No responsible organization will adopt welding unless it has been demonstrated that products so produced will be at least as efficient in either production or use as the same article constructed by other means. It should follow, then, that these manufacturers are overlooking an opportunity if they do not advertise in every possible way that their product is welded, and that it is better because it is welded.

This can be done in a great many ways, all of them on the basis of stressing welding as a favorable feature in the construction of the product. It could be mentioned in advertising copy written for publication use, indicating that welding is synonymous with strength, tightness and dependability, and that through welding light, rugged, trouble-free metal joints are consistently made. All of the favorable factors that recommended welding to the manufacturer or contractor will recommend it to his customers or clients.

In booklet copy, the importance of welded joints and the characteristics or performance possibilities of welded equipment can very well be stressed and very nicely illustrated, and salesmen can be instructed to emphasize the favorable features which are the outcome of welding in their discussions with prospective customers. In many instances the product itself can be packaged or marked in a way that will draw attention to welding as a favorable feature.

Of course, a number of concerns are taking this advantage at the present time. A leading manufacturer of automatic refrigerators in all sales and instruction literature emphasizes the fact that units are welded and are therefore permanently leak-proof. A manufacturer of wood-working machinery prominently displays with every illustration in his catalog a statement that the bases of the machines pictured are of welded steel. A number of piping contractors, jealous of their reputations for high quality work, suggest to the architects with whom they contact and their clients and prospective customers that welding should be seriously considered for major piping jobs.

The AMERICAN WELDING SOCIETY might very consistently encourage, or even aid in the development of this idea. At the present time we have a Society without a Publicity Committee. Let this Society realize that the advancement of the science and art of welding, the Society's published purpose, involves not only the technical problems of putting the science and art of welding in the position where it can advance, but, further than that, it involves actively aiding the advance by some measure of energetic selling effort.

During the last few years the man who built the better mousetrap and waited for the world to beat a path to his door has starved to death! Not only that, but his door has fallen down and the mousetrap has entirely gone to pieces. Someone else, with a mousetrap probably not as good, but efficient enough to catch mice, who has imagination enough and energy enough to promote his own interests, has a major share of the mousetrap business.

As an industry, we have no organized means for placing the story of welding before those who can influence the acceptance of this process most readily, either within the confines of the engineering profession or in the great general public outside. The welding industry has built, technically, a remarkable process. Should we not now, and at this particular time in the industrial cycle, especially utilize every effort to promote it?

The Welding of High Nickel Alloys

By J. G. SCHOENER *and* F. G. FLOCKE

†Paper presented at the Fall Meeting of the American Welding Society in Buffalo, Oct. 4, 1932, by J. G. Schoener and F. G. Flocke of the Development and Research Dept. of The International Nickel Co., Inc.

THE several materials being considered in this discussion are Monel metal, nickel, Inco chrome nickel and nickel-clad steel. This paper will discuss electric fusion welding as applied to these alloys and metals.

A few general remarks relating to the uses to which these corrosion-resisting metals are put and their make-up may be of interest.

The diversity of Monel metal uses are dependent in no small measure on the combination of physical and corrosion-resisting properties and its workability. Monel metal resists a large variety of acid, alkaline and salt corrosives under widely varying conditions. Its versatility can be judged by the few examples following. In the salt industry it is used for rotary salt drier linings, conveyors, centrifugals and chutes. The laundry and dry-cleaning fields find it useful in large and small cylinder washing and dyeing machines and pressure tanks of welded construction. In the textile industry Monel is used very largely in dyeing machinery for silk, cotton and rayon. The chemical field has many uses for Monel such as mixing tanks, conveying machinery, filtering equipment, vacuum evaporators, kettles, condensers and stills. Monel finds uses in the canning field as brine tanks, brine separators and kettles. The kitchen in the home now has Monel sinks, cabinets and domestic hot-water boilers.

Its composition is approximately two-thirds nickel and one-third copper, with minor, but essential, quantities of magnesium, manganese and carbon.

Nickel finds its greatest outlet and, in fact, is unsurpassed by any of the commercial metals in certain fields where it must operate under rather severe conditions. This is true particularly in the chemical fields embodying the manufacture of caustic soda for rayon, the ammonia oxidation process for the making of nitric acid and in the photographic industry.

Contamination of caustic by copper, manganese and iron makes the caustic unsuitable for the manufacture of rayon. Large caustic evaporators, built wholly or partly of pure nickel or nickel clad steel and employing thousands of pure nickel seamless tubes, are now in operation in the production of pure caustic. A caustic evaporator, 24 ft. diameter, under construction, one of four similar units, is shown in Fig. 1. A somewhat smaller caustic evaporator, 5 ft. diameter, is illustrated in Fig. 2.

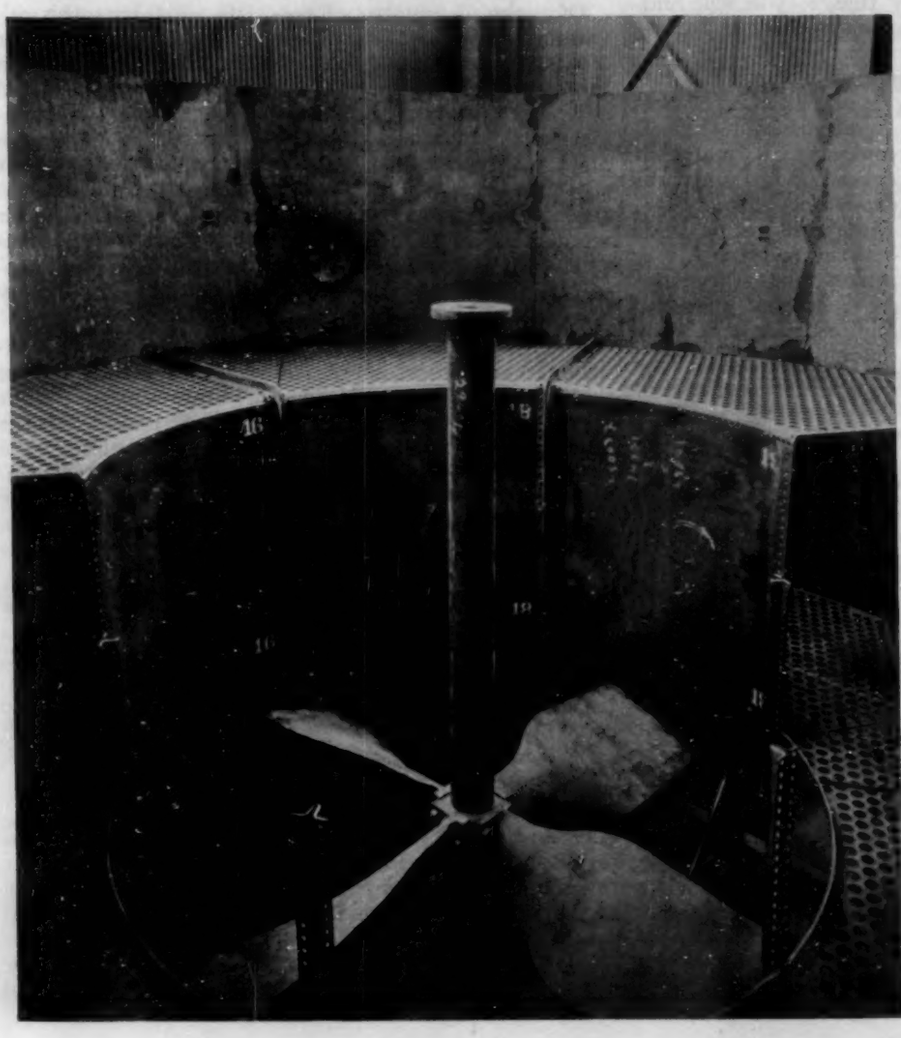


Fig. 1—Caustic Evaporator, 24 Ft. Diameter, 1/2-In. Nickel Tube Sheets, 4200 Nickel Tubes

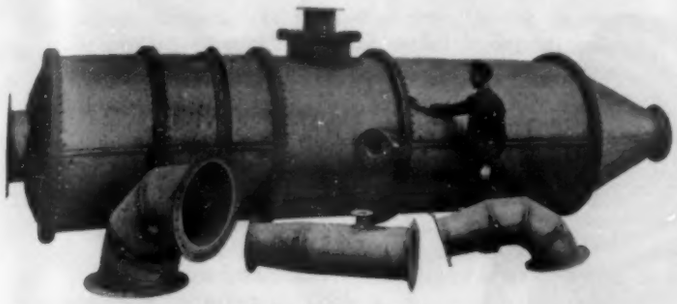


Fig. 2—Caustic Evaporator, 5 Ft. Diameter by 20 Ft. Long, 1/4-In. Nickel Plate

In the ammonia oxidation process, whereby nitric acid is synthetically made from ammonia and air, pure nickel is used for all metal parts that are in contact with the hot ammonia-air mixture. A unit made by acetylene welding a special nickel casting to rolled nickel has been in satisfactory service at 950° C. for some 13 months.

Nickel is required in large quantities in the manufacture of photographic gelatines, films and chemicals. Welding is invariably the means employed to fabricate the intricate shapes and pieces of equipment needed, which includes evaporators, storage tanks, mixers and vats and pipe lines.

Pure nickel or nickel, the terms commonly applied to the commercial product, is 99+% pure. Such alloying elements as silicon, manganese or titanium are sometimes added where a specific set of conditions must be met.

Inco chrome nickel, essentially a material of high quality, and relatively newer than Monel or nickel, was originally introduced for use in the food products and dairy industries. This metal is non-tarnishing in any form or finish. It is used in the food industry for the preparation and handling of cereals, foods and soups, in the form of steam jacketed kettles, coils and tanks. In the dairy industry it is made into pasteurizing equipment and buttermilk machines. Included in this last category are all-welded tanks, coils and linings.

Inco chrome nickel is essentially nickel to which sufficient chromium has been added to produce a metal that is free from tarnish. The chromium content is approximately 14%, and since the chromium addition is as ferro-chrome, there is a definite iron content.

Fig. 3—Bend Test, Nickel Clad Steel. Note uniform thickness of nickel at bends

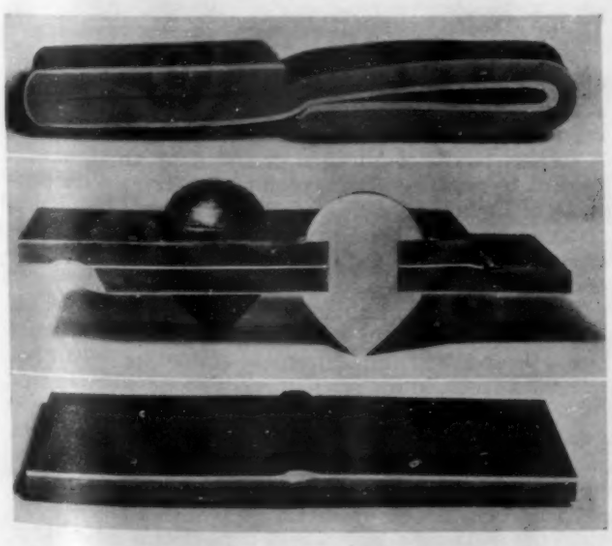


Fig. 4 (Center)—Type of Joint Used in Tank Car Shown in Fig. 7

Fig. 5—Typical Butt Weld, Showing Cross of Nickel Weld Applied

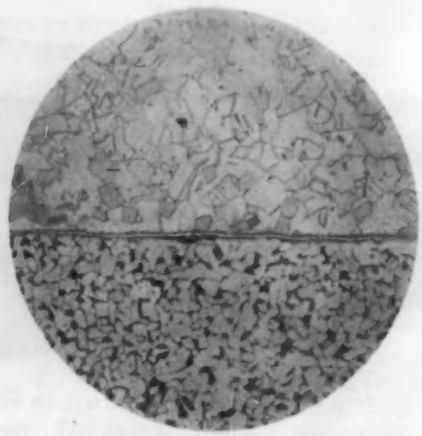


Fig. 6—Typical Nickel to Steel Bond. × 100

The mill products available for Monel metal, nickel and Inco chrome nickel are sheet, plate, strip, rod, wire, angle, seamless pipe and tubing.

Field welding practice and recent laboratory work on the electric fusion welding of these alloys by the authors will be the theme of this paper. Only occasional mention will be made of oxyacetylene welding, as this subject was presented last November by the authors before the International Acetylene Association. That paper, "Gas Welded and Brazed Joints of High Nickel Alloys," brought out in some detail the general procedures in the gas welding, silver soldering and brazing of the alloys being considered here.

It is hoped that the recent improvements and developments in the electric welding of all these alloys and, in addition, several high nickel bearing alloys will contribute to more uniform and better welding, and thus add to their usefulness and easy workability.

That the welding of these metals is thoroughly practical is seen in the fact that they have been welded almost since their respective introductions. Welding is one of the most sound and rapid methods of joining of these alloys. As a standard of comparison, properly made welds should duplicate in strength, soundness and ductility those in ferrous and readily welded non-ferrous alloys.

Sound welds can be consistently produced by the method discussed here, free of porosity and cracks and with good strength and ductility.

Metallic Arc Fluxes

The most essential feature of metallic arc welding of high nickel alloys is the possible deleterious effect of air in the immediate vicinity of the molten metal. As the droplet of metal leaves the electrode and when it lays as deposited molten weld metal there are large areas exposed to the surrounding air. The time during which each droplet is molten is relatively short, but the high temperature of the globules, well above the melting point of the alloy, is sufficient to permit the oxygen of the air to be absorbed, and cause both a brittle and porous weld. If, for example, a bare rod of Monel metal or nickel is used for metallic arc welding, there will be a wild sputtering unstable arc, with a very porous weld of no strength resulting. Besides, certain essential ingredients in the original welding wire will be oxidized, this also contributing to brittleness.

If now a thin coating be applied to the welding rod, the air will be excluded to a very slight extent, resulting in

Fig. 7—First of Two 8000-Gallon Tank Cars Built of Nickel-Clad Steel

a more stable arc and with less porosity. As early as 1922, a coating of magnesium, silicon and manganese was used on Monel metal, which, considered in the light of that year, was giving good results.

A real advance was made as a result of laboratory work evolving a coating having titanium and calcium as active ingredients, and reported before the AMERICAN WELDING SOCIETY* in 1929. The mechanics by which this coating operated is best given by quoting from that paper. "The operating principle of this coating material is that the calcium, being highly volatile at arc temperatures, forms a harmless vapor jacket displacing air from around the arc, while the titanium, resisting vaporization, persists as a highly reducing element in the fusion protecting it from oxidation."

This coating, applied to both nickel and Monel metal, and in use for about three years, produced more consistently satisfactory results in the metallic and carbon arc welding of these metals than previously possible. For example, elongations as high as 27% were obtained with dressed metallic arc welds in Monel and tensile strengths in the weld about 60,000 lb per sq. in., while with carbon arc welds, elongations of the order of 33% and tensile strengths about 55–60,000 lb. per sq. in. Even with these advances, further experimental work was continued in the laboratory. It was seen that some important changes could be effected, because of a certain lack of facility in welding, particularly the tendency to pile up and not penetrate in starting a weld on cold metal. This work was carried on in connection with other alloy welding studies which produced our new alloy, Inco chrome nickel.

The heavily fluxed rod, in all three metals, has been used in a wide variety of field work producing welds of high ductility and toughness, with excellent soundness and strength. It is superseding as the standard for these alloys, the older type of thinly coated rod being available now for general use.

The mechanics whereby these coatings operate are relatively simple. One group of constituents serves as the stabilizing and slagging element, stabilizing the arc and providing a protective coating on the deposited metal. By using a heavy coating, a shield is actually maintained around the core, confining it as it is melting and providing a good mechanical barrier to any surrounding air that would otherwise be present very close to the arc. Another group has the effect of so controlling the plasticity of the coating that a flux shield is always maintained beyond the end of the welding rod, and that it makes proper contact with the melting alloy in the form of a very thin film of flux around each individual globule. A third group has a metallurgical effect, that of deoxidizing and otherwise purging the molten metal of impurities. A further factor of safety is provided by an element in the flux to combine with oxygen at the elevated temperatures of the arc. In this present flux, ferro-titanium is retained as one of the elements because of its highly reducing character. Cellulose is not included in the coating.

Because of this combination, it is possible to deposit a sounder weld, free of porosity, with good ductility and strength and with an extremely stable arc. This last point is a factor in the production of sound welds in high nickel alloys as in other welding. The welder can give greater attention to the flow of metal and watch the weld more closely than when he is troubled with attempts to maintain a steady arc.

The mechanics of operation of this flux and its constituents make for a high rate of deposition. This higher speed is at once seen to be of definite advantage. The rate of melting was at one time so high, and the metal so fluid, that it was not possible to lay a good fillet weld of

* Paper "The Production of Ductile Welds," Annual Meeting, AMERICAN WELDING SOCIETY, April 1929.

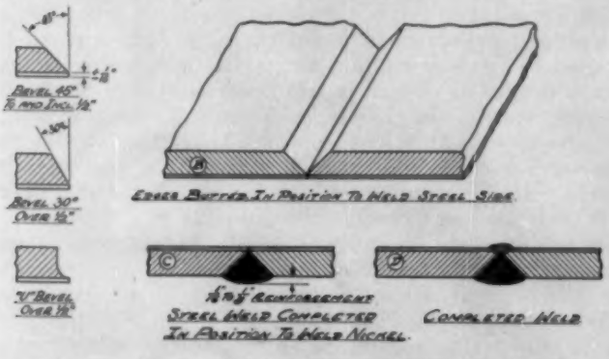

Bevel 45° To and Incl. ½"
Bevel 30° Over ½"
¼" Bevel Over ½"
Edges Buffed In Position To Weld Steel Side
¼" Reinforcement
Steel Weld Completed In Position To Weld Nickel
Completed Weld

Fig. 8—Preparation for Butt Joint

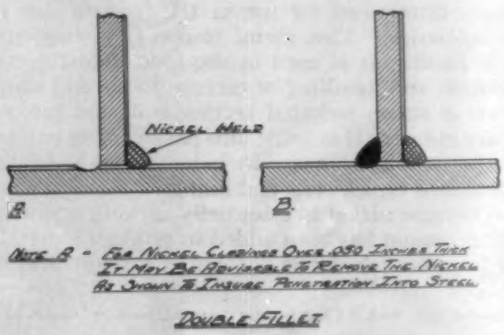

Nickel Weld
A
B
Note A - For Nickel Cladding Over .050 Inches Thick It May Be Advisable To Remove The Nickel As Shown To Insure Penetration Into Steel
Double Fillet

Fig. 9—Double Fillet. Note that nickel is chipped off where steel weld is to be laid

proper cross section. It had, therefore, to be slowed down somewhat to make the rod useful under all field conditions. This is the form in which it now is.

Test Results

Since the introduction of the new flux, certain tests have been made. Tabulated results on Inco chrome nickel are the only available at this writing, but informal comparisons show the nickel and Monel to be of high quality. The gathering of further figures on strength and ductility is now under way. Results of tests for Inco chrome nickel are given in Table 1.

There are two values given in the strength column, that of the weld and of the plate for two sets of conditions, one for the raw welds and that for the machined or dressed weld.

The values for the raw metallic arc welds give the strengths obtainable from the joint as a whole, such as would be encountered in practice. The seemingly low values for weld strength are actually load calculated to the cross section of the weld, and are, therefore, really stress in the weld at failure and not strength of the weld, for the large majority of specimens failed away from the welds.

The quality or goodness of the weld metal is given in dressed weld tests, in which the weld was machined, both sides, but not quite flush with the plate. Even in these, the greater number of fractures occurred in the plate.

The joint efficiency given for the raw butt welds is a comparison of the complete welded joint, as welded, to the unwelded plate. These, as can be seen, are quite good.

Complete bend tests of all three metals on gages up to 1/4 in. have been made in which the bend is across the weld. That the weld metal is ductile is seen in the fact that no fracture occurs even when the parent metal and the weld have been hammered back to back along the entire length.

Welding Technique

In the use of these welding rods, reversed polarity under all conditions is desirable. Generally a lower heat than would be used with the older type Monel and nickel rod is recommended. Actually the setting of heat is not in too narrow a range, so that some leeway is provided.

Table 1—Tensile Tests on Inco Chrome Nickel Welds

Type of weld	Thickness	No. of Tests	Breaking Strength Calculated to Cross Section of Weld	Breaking Strength In Plate	Elong. Across Fracture %	Joint Efficiency
Unwelded	1/16	2	....	90,150	52.3	...
Unwelded	1/8	2	....	95,875	47.8	...
Metallic arc butt joint (raw)	1/16	3	49,570	89,880	38.3	95%
Metallic arc butt joint (raw)	1/8	3	54,650	97,200	31.7	100%
Metallic arc butt joint (dressed)	1/16	6	74,315	89,875	39.4	...
Metallic arc butt joint (dressed)	1/8	6	89,190	95,625	34.5	...

In welding of nickel alloys, the molten pool of metal should be quiet and not boiling. Agitation of deposited metal is not necessary to the complete removal of gas from the weld, as this is absorbed by the fluxing material. Furthermore, minor quantities of essential ingredients present in the alloys, such as manganese, magnesium, silicon, etc., must be retained during and after welding to insure ductility and toughness of the alloy. Any excessive boiling or puddling of the molten metal would tend to remove these vital elements, thus rendering the alloy less useful.

Setting-Up

The metallic arc welding of the lighter gages generally presents a problem of clamping and backing up, though not in all cases. It has been found that where production is really a factor, any reasonable time spent in the design of jigs or clamping devices is well repaid in better finished work and fewer rejections. The usefulness and advantages of clamping of work to be welded holds as well, and possibly more so, for gas welding.

Nickel-Clad Steel Plate

Nickel-clad steel plate, as the name implies, is a flanging quality steel with a cladding or veneer of pure nickel on one side. The nickel cladding is permanently bonded to the steel plate, and possesses the same chemical and physical properties as hot rolled or hot forged nickel. The material is available in thicknesses of 3/16 in. and over, with the nickel cladding supplied as 10, 12.5, 15, 17.5 and 20% of the total thickness of the plate. The tensile strengths developed by the bimetal are slightly higher than the flange quality steel, as noted in Table 2.

Table 2—Comparison of Nickel-Clad Steel and Steel Strength and Ductility

From a Lukens Steel Company Report

	Yield Point P.S.I.	Ultimate Tensile Strength P.S.I.	% Elong. in 8 In.	% Red. of Area
3/16-In. plate with 0.050-in. nickel cladding				
Carbon steel	42,200	51,200	41.75	72.9
Nickel-clad steel	45,600	57,500	29.0	52.8
1/4-In. plate with 0.050-in. nickel cladding				
Carbon steel	36,800	60,300	27.5	50.7
Nickel-clad steel	40,500	60,900	30.0	58.0
5/8-In. plate with 0.062-in. nickel cladding				
Carbon steel	32,900	61,000	26.3	58.8
Nickel-clad steel	40,300	61,800	30.0	62.5

NOTE: The thicknesses given are total thickness of plate, with the cladding as a part of it.

The usefulness of this metal is in large equipment where a corrosion-resisting surface is needed, and where the cost of a solid corrosion-resisting metal would be prohibitive. Two 8000-gal. railroad tank cars, made of nickel-clad steel, are now in service for the shipment of pure caustic to the rayon plants. Caustic evaporators have been made in part of nickel-clad steel. Soap-boiling kettles, water-heater tanks for the storage of hot water in hospitals and truck tanks for hauling liquids, all made of nickel-clad steel, have proven highly satisfactory.

The welding of nickel-clad steel is different from steel plate welding in only one respect. For a butt joint (see Figs. 5 and 8) the bimetal is veed and welded from the steel side with steel welding rod, using either electric or oxyacetylene welding. The weld metal at the base of the vee is gouged out from the underside, to clean the seam of icicles and oxide, so presenting a clean groove into which the nickel can be welded. Up to this point the procedure is similar to regular steel practice. The only change now is to use nickel welding rod to join the nickel edges, so insuring a continuity of nickel at the seams. With corner welds, the steel is again welded

first, then the nickel, but here no chipping is necessary on the nickel side.

Though the greater majority of the work to date has been with electric welding, because it was thought there might be excessive pollution by iron when laying on the wash weld of nickel with oxyacetylene, this latter method has been found applicable, particularly for vertical welding. For butt joints on thinner plates, it has been found useful too.

The purity of weld laid on the nickel side, is of importance, and for that reason, the possible deleterious effects of iron contamination in the nickel weld were given some thought.

It was found that with even as much as 20% iron in an iron-nickel alloy the resistance to attack by aerated 50% sulphuric acid at 20° C. was decreased by only 20%. With caustic soda the effect of iron was of even less practical importance. Tests in a caustic concentrator showed that with as much as 70% iron the rate of corrosion of nickel was increased from 0.0001 in. penetration per year to 0.0004 in. penetration per year. Both these rates were extremely low. However, the best demonstration of the corrosion resistance of welds on nickel-clad steel has been the uniformly excellent behavior of numerous pieces of welded equipment in several types of service.

Analysis of nickel weld metal shows the iron pick-up to be of reasonable proportions, but can be kept at a very low figure by care in design and fabrication.

Butt weld	(Electric welding)	4– 8%
Lap weld	(" ")	7–15%
Fillet weld (Nickel inside)	(" ")	3– 7%
Butt weld	(Oxyacetylene welding)	Max. 15%

In conclusion, it can be said that continued laboratory work has brought about improvements in the metallic arc welding of high nickel alloys and nickel-clad steel. That the making of welds with excellent physical and corrosion-resisting properties is thoroughly practical is evidenced by the many pieces of equipment of these alloys giving satisfactory service.

All-Electrical Arc-Welded Steel Penstock

By CLAYTON M. ALLEN

†Paper presented at the September 22nd Meeting of the Los Angeles Section, American Welding Society, by Clayton M. Allen, Junior Electrical Engineer, Los Angeles Bureau of Power and Light.

COINCIDENT with the placing in service of the third 17,500-kv-a. hydro-electric generating unit in the San Francisquito Plant No. 2 of the Bureau of Power and Light, Department of Water and Power of the City of Los Angeles, in October 1932, was the successful start of operation of the first rivetless, all arc-welded steel penstock in the United States.

San Francisquito Power Plant No. 2 is located 45 miles north of Los Angeles, and is one of two plants in the canyon of the same name connecting to the Bureau of Power and Light system five hydro-electric plants on the lower end of Los Angeles Aqueduct, the largest municipally owned electric utility in this country.

The hydro-electric development in San Francisquito Canyon was designed to utilize the head developed by the Aqueduct from Owens River to Los Angeles. Approximately eighteen miles of waterway, made up of tunnels, penstocks and two siphons, all designed for a maximum flow of 1000 sec. ft., are utilized for power generation in this area. A 940-ft. static head is employed at Power Plant No. 1, which has a capacity of 75,000 kv-a.

Power Plant No. 2, now developed up to ultimate installed capacity of 52,500 kv-a., is approximately 6½ miles below Power Plant No. 1 and is connected thereto by a 1000-sec. ft. tunnel with a surge tank above the power plant.

From the surge tank in the aqueduct system above Power Plant No. 2, three belled, 7-ft. pipes lead to a valve chamber. There are three butterfly valves in this compartment and from there three penstocks lead out through 164-ft. tunnels to the open and from there are laid down the side of the hill on suitably prepared concrete piers at approximately 25-ft. intervals.

The first two riveted penstocks and the third electrically welded penstock, each 1400 ft. long, 7 ft. in diameter at the upper end, tapering to 6 ft. at the bottom, carry water to three 20,500-hp. vertical reaction turbines operating under a static head of 530 ft.

The lower portion of the penstock on the brow of the hill is laid on concrete piers, anchored to a ridge of schist of a harder texture than most of the rock in the vicinity. This harder dike extends across under the creek channel to the west side of the canyon. The foundations of the power house, situated in what was the bed of the creek and the foundation of the generating units and lower penstock anchors are in this bedrock.

In addition to the three generator units, the main equipment housed in the power plant consists of ten 5833-kv-a., 6.6/110-kv. transformers, ten 110-kv., 3-phase oil circuit breakers, two banks of lightning arrestors on the ground in the rear and a 100-ton crane of 36 ft. span. The high voltage conductors lead out through the roof to the 110-kv. transmission line which delivers the electrical energy to Los Angeles some 50 miles distant.

In the preliminary design of the third unit penstock, it became evident that an all arc-welded penstock would have its advantages over the older and previously used riveted pipe line, because of the saving in friction losses.

Specifications for fabricating the new penstock made provision for receiving bids on both the riveted and shielded arc-welded penstock. The bids revealed that the shop fabrication of the welded line would cost approximately 13 per cent more than the riveted design. The saving in the cost of installation of the welded penstock, it was estimated, would offset the increased fabrication cost. In addition, the increased efficiency due to reduction in friction loss by elimination of rivets and butt straps was calculated to result in a large return over a period of years because of the increased output.

These considerations resulted in the Bureau's engineers recommending and the purchasing of the welded penstock.

The Consolidated Steel Corporation of Los Angeles fabricated the complete penstock line, consisting of 40 straight sections, 9 elbows and two expansion joints, comprising 309 tons.

All plate was rolled by the Lukens Steel Company and conformed to the A. S. T. M. Specifications for Steel

Plate of Flange Quality for Forge Welding, A89–30, Grade A, and was in such lengths as to require but one longitudinal weld. Plates of about 9 ft. in width were used, three being shop welded together into approximately 27-ft. sections for field assembly.

The diameter of pipe varies in 3-in. steps from 7 ft. at the top to 6 ft. at the bottom. Thickness of plate varies from 3/8 in. to 7/8 in. in steps of 1/16 in. according to the pressure and location in the line, the heaviest plate being at the lower end. Of the total line 900 ft., or 64%, is of 3/8-in. plate 7 ft. in diameter.

The nine elbows in the line turned horizontal angles of from 3 to 26 deg. and vertical angles of from 3 to 22 deg. There were 4 compound angle elbows. Changes in pipe diameters were accomplished by short tapered sections.

All longitudinal joints were machine butt welded in the shop. Specially built machines designed by engineers of the fabricating company and the carbon-arc "Tornado" were used on these welds.

A specially developed round seam welder also developed by the fabricating company was used on the inside circumferential joints. The outside welds were made by hand, using 1/4-in. covered electrodes.

A novel inclined structural steel rack was designed and used on the outside hand lap welds. The pipe sections were put on this rack and by means of motor-driven rollers slowly rotated so that welders sitting on horizontal platforms could weld with the work always in the flat position. Three welders could work at once, one to a plate on 3 plate sections.

The circumferential joint selected was of the coupling type employing a butt strap. The ends of the two sections to be joined were turned to a 2-deg. taper on the outside for a distance of 4 in. and beveled on the edge to an angle of 30 deg. An outside butt strap 8 in. wide and of the same thickness as the plate was taper turned on the inside to fit the ends of the pipe. When the sections were brought to within 1/4 in. of each other, a welding "V" was formed with 1/8-in. straight sides and the balance beveled leaving a 60-deg. angle to be filled with weld metal. Taking into account the bevel, the result was that the thickness of metal in butt welds inside and lap welds outside was in every case 1/8 in. less than the plate thickness. One exception to the butt strap thickness was the case of the field joints on the 3/8-in. pipe wherein the thickness of butt straps was 7/16 in.

In each piece, whether elbow or straight section, the shop welding was completed with the butt strap for the field joint on the upstream end, thus facilitating erection and field welding.

The final procedure in welding the shop joints was to tack-weld the inside butt joint and one outside lap joint, and then finish the butt and lap welds in that order so that locked-up stresses might be reduced to a minimum. Next, the closing outside lap joint was welded.

Test specimens of the same material as the plate were attached to one end of each section as the longitudinal weld was made. The specifications called for samples to be cut from the welds in the finished section. However, this method of testing was resorted to only once.

All welding tests were conducted in accordance with the A. S. M. E. Boiler Construction Code for Unfired Pressure Vessels, Class 1, and were required to comply therewith before being accepted. The only exception were sections made of plates of 7/16 in. and 3/8 in. thickness which were not stress relieved.

In the different types of welding on various thickness of plate the number of passes or layers was of interest. The machine welds on the 3/8-in. plate were made in two passes, one outside and one inside. On the same weld of greater plate thickness the number of passes ran as high as four on the outside and one inside.

On the inside round seam machine welding, the number of layers varied from two to three according to plate thickness. The only exception to this was the case of a few single pass machine welds which had a second pass applied by hand. The hand welding, on the outside lap welds, and some inside butt welds, was done in a flat position as far as was possible, and with 1/4-in. electrodes the number of beads varying from one to four. The elbow sections required more hand welding, and slight difficulties were encountered due to inability to readily turn them.

A rather unique method of testing the finished welded joint for the segregation of leaks, between the butt or lap weld, is of more than passing interest. Holes 1/4 in. in diameter were drilled through the butt strap of each shop joint from the outside, one on each side of the butt weld. This allowed a high pressure soap test to be applied on each lap weld and two tests on the butt weld. The advantage of this method over the pressure test from the inside of the pipe is readily seen in that the butt weld may have had a small pinhole leak which would not appear on the outside through lap welds in which there were no leaks.

All straight sections and elbows 1/2 in. thick and over were stress relieved in accordance with the A. S. M. E. Boiler Construction Code for Unfired Vessels. Elbows were stress relieved in two heats, one to an end. Each piece was thoroughly braced internally before being relieved to minimize deformation. The length of time in the furnace at 1100° to 1200° F. was about an hour. Each section was allowed to cool in still air.

A hydraulic test of 5-min. duration was given each piece and at the same time the welded seams were pounded with an 8-lb. hammer. In testing the elbows the ends were left long, and dished heads welded on each end in order to conduct the water pressure test. Testing was done after stress relieving. After testing, the heads were cut off and the elbows laid out on the floor and checked for dimension and alignment. The straight sections were checked for length. Test pressures ranged from 180 lb. per sq. in. on the 3/8-in. pipe to 485 lb. per sq in. on the 7/8-in. pipe.

After each section successfully passed all tests it was subject to the final fit with the adjacent section. This was extremely important for a misfit on a 10-ton piece of pipe high up on the side of a hill at an angle with the horizontal of 42 deg. would be rather difficult to rectify in the field.

After being finally released to the shipping yard, the sections were transported by the Bureau's own equipment at such time and in such sequence as was required on the job.

Immediately after the purchase of the electrical arc-welded penstock, engineers of the Bureau started a thorough investigation of field welding of pipes of large diameter and thickness. It was soon found that very little had been done along this line, especially with the shielded-arc, most of the pipe work having been done on gas and oil lines of smaller diameter and lighter plate, and with steel of higher carbon content.

A series of tests was conducted on several samples made by different welders in different positions and under conditions approximating the actual job. This was done to develop procedure for the field welding and it was of paramount importance because only quality work could be considered. In making these samples both bare rod and covered wires were used.

From observations during the making of these tests and the results of the tensile, bend and wedge tests, many valuable data were secured relative to the method of

application and the behavior of the newer and faster coated rod as well as the reaction of the human element on the part of the welders.

Welders were drawn from the preferred Civil Service List of the City on which are carried all classes of welders. They had been previously tested on acetylene and bare rod arc-welding and when interviewed it was doubtful in most cases if any had ever had experience with coated rod and, if any, it was limited to flat work in fabricating structural steel.

The field welding problem was a two-fold problem, that of developing actual methods and procedure, and that of training and perfecting welders in the art of applying covered electrodes in the field in any position such as might be encountered in the 50 field joints that were to be welded in the penstock line.

The welders on the preferred list who expressed a desire to have an opportunity to try out for the job were taken one at a time and given an opportunity to make up samples which were torn apart and examined for texture, penetration and blowholes. Tests were run on plate of the same quality as the penstock steel and in sizes $^3/_8$ in. and $^7/_8$ in. These sizes were selected because the majority of the field joints were to be on $^3/_8$-in. plate, and the $^7/_8$ in. because that size was to be welded first and it was felt considerable practice should be had with this thicker plate.

The simple wedge tests served more than anything else as a means to examine the welder's work, and many times he was surprised to see the inside of an apparently perfect weld. As the welders became more accustomed to working with coated rod, the quality of work became better as would be expected. Observation of the force which it was necessary to apply with the power hammer to open many of the lap welds was in itself almost a true indication of the quality of the weld. Many times it was impossible to break the weld as the plates would double back upon each other. A common occurrence was to tear the plate metal away rather than to disturb the weld metal.

By varying the number of beads or layers, it was found that the texture of the weld metal improved with a greater number of passes. It was also found that the tendency for blowholes to be included was reduced when more passes were used, and if blowholes were found they were considerably smaller than they might have been on welds of fewer passes.

The great advantage of multiple bead work, in the opinion of the writer, who was in charge of field welding, is the fact that by this procedure it is possible to inspect the inside of the weld while it is being made, thereby tending to overcome one of the so-called objections to welded work by the followers of riveted construction when it is stated that a completed weld cannot be inspected.

As the welders had several practice sessions and became more adept, additional refinements were included in the procedure to insure quality work. Each bead was thoroughly wire brushed before applying the next one and at the end of each bed when an electrode was changed a similar precaution to exclude slag was taken.

By using light-weight, fast-hitting air hammers to peen-hammer each bead as it was completed, it was found that the quality and strength of the weld was greatly increased. Tension tests made on some of the butt welds on the $^7/_8$-in. penstock plate ran over 83,000 lb. per sq. in. of reduced weld sections. As compared with the required plate strength of 45,000 lb. per sq. in. minimum.

Further practice indicated that the work was becoming increasingly better, and we were exceedingly fortunate in that about this time the Water Bureau took up the use of covered electrodes in the field construction of several pipe lines of around 45 in. diameter and employed the Civil Service welders that had been in training for the penstock job. This work gave them actual field experience on pipe about as similar to our conditions as could be had and put the finishing touches on the training course.

The erection of the penstock was piece by piece from bottom to top. The assembly was handled from three points as there were two expansion joints in the line and a concrete anchor at the brow of the hill, making logical construction sections. The start was made on the $^7/_8$-in. sections at the bottom and then a short time later work was started in two places on the $^3/_8$-in. sections.

It was decided to do most of the welding at night when the penstock was not exposed to the direct rays of the sun, and thereby eliminate possible difficulties from temperature changes in the pipe as well as provide a much more agreeable working condition. Also, on the steep part of the hill, about 42-deg. slope, the work was limited as to time as it would have been impossible for welding crews to work on this hill at the same time as the erection crew due to the hazard of falling and rolling rocks.

The ideal program was to erect and tack-weld a section in the daytime and start welding at about sun down in order to get in two 8-hr. shifts before erection of the adjacent piece the next day. This program was carried out on the steeper part of the hill.

The five sections in the penstock tunnel were lined up just outside of the tunnel portal and by means of a bell hole and suitable sunshades welding was done in one location continuously. The completed line was jacked into the tunnel as each new section was welded on.

The welding procedure on each joint was to put in about a half dozen heavy tacks equidistant about the circumference of the inside butt weld and then to proceed with the welding, trying to keep approximately the same number of beads on every part of the periphery. This, of course, had to be varied due to the extreme inconvenience of trying to work on a small level platform inside or upon scaffolding outside with the pipe at a steep angle with the horizontal.

With the inside butt weld completed the outside lap weld was next completed. Often the next section was ready for installation and rather than hold up the work it was placed and welded on the inside before the previous outside lap weld had been finished.

A welding crew consisted of a welder and a helper. The helper was kept rather busy as his duties included the cleaning and peen-hammering of each bead and keeping the welder supplied with all the necessities such as rod, water and electric lights.

In addition to keeping his own cleaning and peening tools in condition the helper filled in a welder's daily report card which gave a record of the joints worked on, time out waiting for machines to be built or scaffolds erected, the number of each size rods used, $^5/_{32}$ in. and $^3/_{16}$ in., and the reading of the watt-hour meters on the motor-driven welding generators at the start and finish of each shift, or when changing from one joint to another.

The last sections to be installed were the two expansion joints both located in the $^3/_8$-in. 7-ft. pipe, one at the brow of the steep part of the hill below the concrete anchor and the other just below the upper 375 ft. which was on a very slight slope. These joints take up the expansion and contraction in the line due to the temperature changes and the cast-iron saddles on top of the concrete piers are grooved for oiling so that free movement of the penstock is possible. The expansion joint is con-

structed of a cast bronze ring sliding inside of a cast steel ring fitted with a ring follower which is drawn up against three rings of $^3/_4$-in. flax packing.

There was a maximum of eight welders on the job. Seven worked at welding, one welder being used as straw boss on part of the work, and one with the erection gang most of the time. Most of the welding was done in two night shifts although, in order not to hold up the work of erection and installation of the turbine, some three-shift work was done. In all there was a total of 1592 welding hours put in from which approximately 143 hours was consumed waiting on riggers, carpenters and moving welding machines. Welding operations started June 20th and on August 22nd the penstock was filled with water with not one leak.

Statistics on Field Welding
3rd Unit Penstock
San Francisquito Power Plant No. 2
Bureau of Power and Light

Ave. of 33 Joints on 84-in.–$^3/_8$-in. Sections on Angles from 0 to 40 Deg. with Horizontal

	Time, Hr.	Electrode, Lb.	Energy, Kwh.	Beads	Electrodes per Hr., Lb.	Kw. H./ Hr.
Butt Weld	12.8	20.7	48	10.3	1.62	2.2
Lap Weld	11.0	18.9	46.2	8.4	1.73	2.4

Ave. of 17 Joints on 81-in.–$^7/_{16}$-in. to 72-in.–$^7/_8$-in. Sections on Angles from 20 to 42 Deg. with Horizontal

	Time	Electrode	Energy	Beads	Electrodes per Hr., Lb.	Kw. H./ Hr.
Butt Weld	28.2	44.0	106	24.3	1.56	3.76
Lap Weld	19.1	30.5	69	16.7	1.60	3.61

Average of Entire 50 Welded Joints

Butt and Lap Welds	31.8	50.8	121.5	..	1.59	3.82

NOTE: An average of 3 in. or 21.4% of each 14-in. electrode was waste.

Previous to erection and welding all sections were sand-blasted and painted inside with a bitumastic enamel supplied by the Wailes-Dove-Hermiston Company; after the line had been filled the outside service was given a two coat job of graphite paint supplied by the Detroit Graphite Company.

Statistics on the actual time of welding, including waiting on riggers and carpenters, the actual count of electrodes by the helpers, the energy consumption and the number of beads applied, is shown in the following tabulation. Due to the large quantity of 7-ft. pipe of $^3/_8$-in. wall thickness average figures are given for this work. The other work was so varied as to diameter and thickness of plate as well as field welding conditions that figures for that work are all averaged together.

The story of this interesting and rather pioneering job would not be complete nor would it be fitting to fail to mention the enthusiastic and whole-hearted cooperation given the Bureau by the representatives of the various contractors who supplied materials and equipment that went into this penstock. The personnel of the companies was at all times ready to assist and offer the results of their experience toward the success of the project.

It is especially appropriate at this time, I believe, to particularly compliment the men who did the field welding for in their hands largely rested the success of the efforts of all others. The record of no leaks is in itself a mark of distinction.

The engineering and construction work was handled by the Bureau itself, of which Dr. E. F. Scattergood is Chief Electrical Engineer and General Manager, the project coming under Mr. H. C. Gardett, Engineer of Design and Construction, Mr. Charles P. Garman, Assistant Engineer of Design and Mr. R. R. Robertson, Engineer of Construction. Detail engineering and design was in charge of Mr. A. E. Bratfisch, hydraulic and mechanical design, Mr. H. G. Butterfield, Resident Engineer, Mr. Chas. W. Ragan, Superintendent of Construction and Mr. Clayton M. Allen, field welding. Mr. M. R. Dougherty was inspector on our shop fabrication.

Final Report
Committee on Welded Rail Joints

Every member who desires a copy of this book of 350 pages is urged to place his order at once. Only a few hundred copies were printed for general distribution. The supply is being rapidly exhausted. Price per copy $1.00. This book summarizes the extensive investigation made by the Welded Rail Joint Committee over a period of ten years involving nearly a hundred thousand dollars in materials, services and cash.

Many of the investigations are fundamental and are of interest to other industries and applications of welding.

AMERICAN WELDING SOCIETY
33 West Thirty-ninth Street
New York, N. Y.

Researches in Arc Welding*

By G. E. DOAN *and* J. L. MYER

†Prof. G. E. Doan is Associate Professor of Metallurgy, Lehigh University. This paper is a contribution to the work of the Fundamental Research Committee of the American Bureau of Welding.

IN INDUSTRIAL electric arc welding it is often difficult to say, once good or bad results have been obtained, just why they are good or why bad, and if bad just which of the dozen or more variables in the process was responsible. Obviously many inferior welds are being made in this maze without leading to any definite conclusion. Some of the variables are:

1. Kind of steel welded—that is, the chemical composition, heat treatment, amount of included matter and surface condition of the parts welded.
2. Kind of electrode wire used.
3. Preparation of parts prior to welding.
4. Kind of welding machine used.
5. The human element in the operator's work.
6. Subsequent heat treatment of weld.
7. A host of others.

It has been proposed that this admittedly complex but industrially important problem be studied by statistical methods in which each variable in every welding operation, together with the degree of success of the operation, be recorded on a series of cards which could then be sorted and the rôle of each variable so evaluated. The other obvious method of attack is the method of abstracting the basic simplified system from the usual complex system; such as using *pure* iron for electrodes and for the parts to be joined, and performing the welding in an inert and therefore non-participating atmosphere. This latter is the method adopted by the present authors and supported by the A. I. E. E. through a grant from Engineering Foundation in 1930, and supported also by Lehigh University.

The successful completion of this project should establish a base line both for the behavior of arcs and for the qualities of welds of pure iron in a non-participating atmosphere. Once the characteristics of an iron arc are known and once the physical, chemical, mechanical and metallurgical properties of pure iron welds are established, all more complicated alloys such as commercial steels then could be referred to that base line as a standard, and a judgment could be made of the effects of each alloy element, whether desirable or undesirable. Thus, questions such as: "What should be the phosphorous or sulfur content of steel for welding? Is nitrogen in steel detrimental for welding? What about the best composition for welding wire? What is the action of air on the arc and on the weld metal?" today unanswered, could gradually be answered by reference to the pure iron base line, and the wastefulness and uncertainty of guessing eliminated.

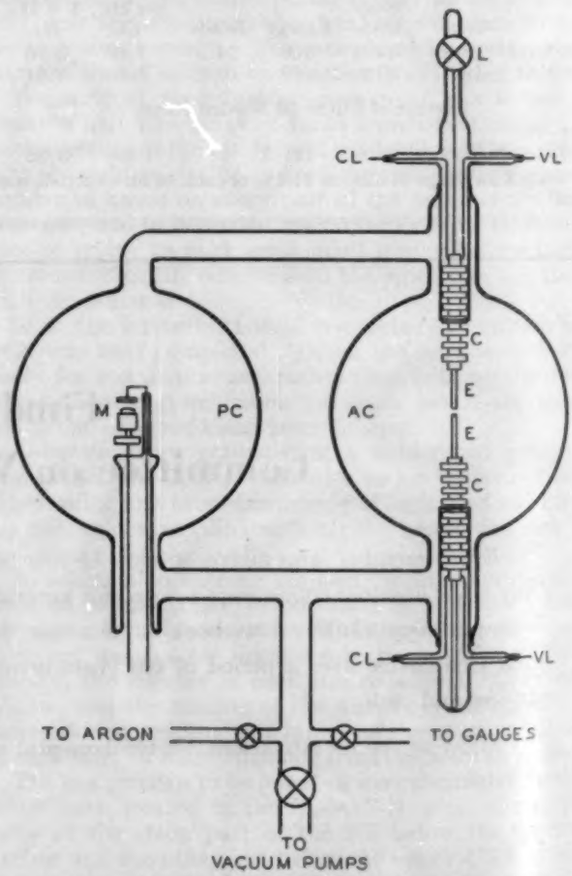
Purity of Materials

Pure iron in the form of wire $^1/_8$ in. in diameter and plates $^1/_8$ in. thick was contributed for these studies. A special method was followed in the preparation of these experimental samples from ferrous chlorid ($FeCl_2$) of reagent grade. This material analyzed as follows:

SO_3	0.0005 per cent
As	0.0000 per cent
Cu	0.0000 per cent
Zn	0.008 per cent

It then was partially converted to oxid by heating in a porcelain dish in an oven. Decomposition was completed by adding chemically pure concentrated nitric acid (HNO_3) and reheating in an oven. The ferric oxid (Fe_2Cl_6) thus produced was reduced in hydrogen in a porcelain tube to give metal powder. After that, the powder was sintered and drawn into a wire, and finally heated in a tungsten grid vacuum furnace.

Argon gas with total impurities amounting to only 0.0003 (30 parts per million), the purest gas obtainable in quantity was used for the experiments. The arc chamber, *AC* in Fig. 1, was made of pyrex glass, as also was the auxiliary purification chamber *PC* and all connections. The auxiliary chamber contained a second arc, supplied by a separate 500-volt circuit. The arc in this chamber had misch metal (reactive metals such as cerium or lanthanum) as one electrode. With such an electrode, the metal which vaporizes from it reacts with any reactive gases in the argon, and the compounds so formed deposit on the walls of the chamber. This has been reported upon in some detail by Dr. Saul Dushman in the Franklin Institute *Journal* for June 1931.



AC, arcing chamber; *C*, electrode holders of copper with cooling fins; *CL*, current leads; *E*, pure iron electrodes; *L*, lug ground into stopcock with device for moving upper electrode; *PC*, purification chamber; *M*, misch-metal purification arc; *VL*, volt-meter leads

Fig. 1—Apparatus Used for the Determination of the Characteristics of Arcs Drawn between Pure Iron Electrodes in an Atmosphere of Argon Gas

* Reprinted from *Electrical Engineering*, September 1932 issue. Work sponsored by the Engineering Foundation.

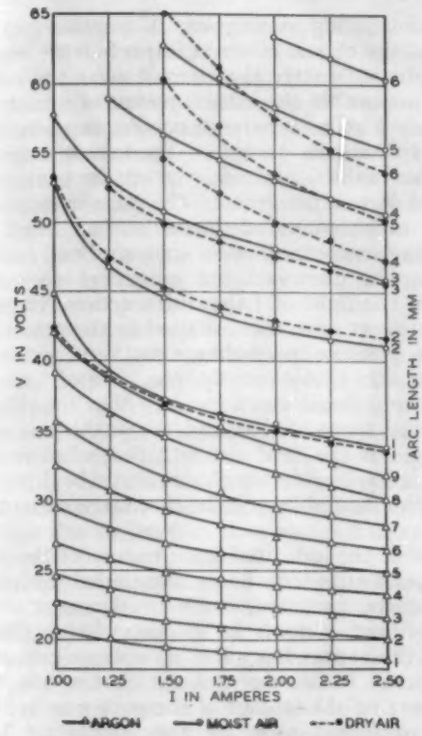


Fig. 2—Comparison of the Voltampere Characteristics of the Iron Arc in Argon Gas, Moist Air and Dry Air

Arcs in Argon

In tests made with argon gas as received, in moist air and in dry air, all metal parts except the iron wires, but including the copper grips *CC* and the glass chambers, were baked out previously in a hydrogen furnace to expel gases. The chambers then were exhausted, filled with argon, again exhausted and filled, and the arc struck between electrodes *EE* by turning the ground glass lug *L*. Runs made without operating the misch metal arc further to purify the argon gas as purchased gave a normal arc discharge at *EE* with an impressed potential of 120 volts. The results so obtained, while valuable, were not especially noteworthy. The length of the arc was measured by projection onto a screen; the current and voltage by Weston standard laboratory meters. The results are shown in the characteristic curves in Figs. 2 and 3. Currents higher than 2.5 amp. could not be used without consumption of the electrode. For comparison with the argon, similar runs were made in slowly circulating dry air and in circulating moist air. These characteristic curves for dry air and for moist air arcs of pure iron are included in Figs. 2 and 3.

As Fig. 2 shows, the arcs in air, both dry and moist, require a substantially higher voltage than the arc in argon. Also, the arc in air cannot be extended to such lengths as the arc in argon, which latter goes to 9 mm. without extinction. In most cases the voltage of arcs of a given length in dry air are lower than in moist air, as reported also by Shrum and Wiest at the 1931 winter convention of the A. I. E. E.[1] Both 1-amp. arcs show irregularly high voltages indicating probably that the arc was in transition between the first and second arc stages. Further information concerning this may be found in papers by S. Maisel,[2] C. P. Steinmetz,[3] Cady and Arnold.[4] At 4 mm. the dry air arc curves of Fig. 3 show breaks at all currents. No explanation for this irregularity is offered at present. In other respects the curves in air and those in argon are quite regular. The 1-mm. curve in argon is approaching rapidly the condition of constant minimum voltage, independent of arc current.

The arc in argon deposited a black coating on the chamber, probably condensed iron vapor; in air the deposit was of a brownish red color like iron oxid. The arc was difficult to strike at first when new electrodes were used in dry air, but not so in moist air.

$$V = A + \frac{B}{l^n} \text{ with } n = 2.62 \times 10^{-4}T$$

(where T is the boiling point of the anode) as given in the *A. I. E. E. Journal* for Feb. 1923, p. 302.

Arc in Drastically Purified Argon

The most astonishing results came when a final drastic purification of the argon as purchased was carried out by circulating it through the misch-metal-arc purification chamber for several hours before the iron electrodes *EE* were touched. In these runs the greatest

[1] *A. I. E. E. Transactions*, **50**, 650–5 (June 1931).
[2] *Phys. Zeit.*, **550**, 1904.
[3] *Trans.* Elec. Cong., St. Louis, **2**, 704 (1904).
[4] *Am. Jl. of Science*, **24**, 383 (Nov. 1907).

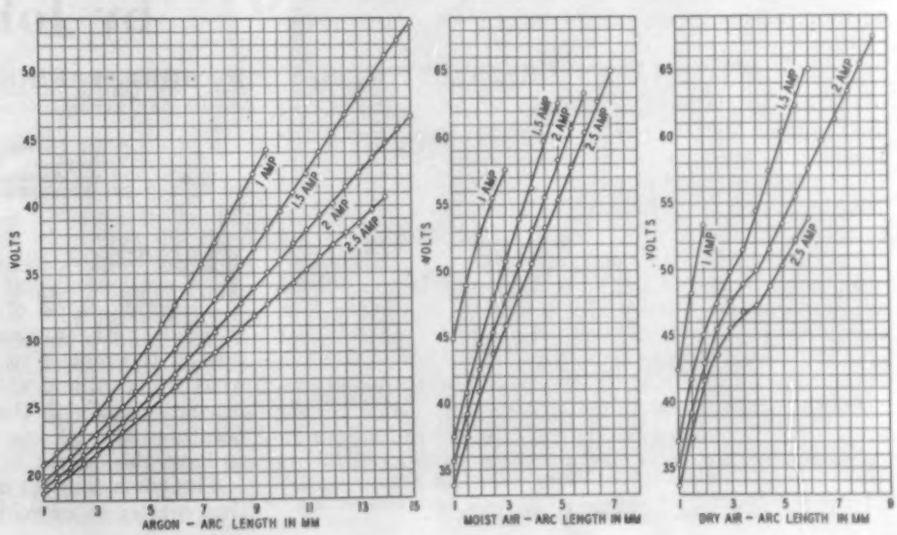


Fig. 3—Comparison of the Voltage-Length Characteristics of Arcs Drawn between Pure Iron Electrodes in an Atmosphere of Argon Gas with Impurities Present (Left); in Moist Air (Center); and in Dry Air (Right)

care was exercised to obtain absolute cleanliness. An entirely new glass system and new iron electrodes were used each time. All parts (except the iron) were thoroughly baked out in the furnace prior to use. After circulating the argon for several hours (by convection) between the purification chamber and the arc chamber proper, the electrodes *EE* with a potential of 120 volts across them were touched and slowly separated. In all cases, however slow and cautious the separation, no arc could be struck. It was simply *impossible* to strike an arc between the pure iron electrodes with 120 volts in an atmosphere of *pure* argon.

The implications of this result are far reaching. It has never been supposed previously that an arc required for its establishment a complex atmosphere, or one containing chemically active gases such as the nitrogen and water vapor which constituted most of the 30 parts of impurity in 1,000,000 parts of "impure" argon as received. The low voltage electrical discharge through gas or vapor (i.e., the arc discharge) has been explained by Dr. K. T. Compton[5] on the basis of thermionic emission from a hot cathode, and by Dr. Irving Langmuir[6] from the accumulation opposite the cathode of a positive space charge which pulls electrons out of the cathode, whether hot or cold. Most arcs can be accounted for successfully by one or the other theory. Neither theory postulates the necessity for the presence of chemically active atoms or molecules in the arc environment, and yet the refusal of the arc to form in the pure gas used in the experiments here reported indicates this new view. Arcs in argon have been reported frequently in the past, but never in a gas so highly purified as in the present studies. It is possible that our most basic conceptions of the nature of the arc discharge may require modification to conform to these observations of the iron arc in argon.

If the rigorousness of the purification were relaxed in the slightest degree—if, for example, the surfaces of the iron electrodes were not scrupulously cleaned immediately before insertion into the chamber—the normal arc would strike without difficulty; or if the copper grips *CC* were not baked thoroughly, a discharge between the lower grip (copper) and the upper electrode (iron) about $1^1/_2$ in. long would set in, and after a minute or so return to the electrode tips as a normal iron arc. In the tests which revealed this possible condition apparently enough gas had been liberated from the impure copper grip to support the arc in the then contaminated argon gas. However, when purification was carefully prosecuted and complete it was impossible to strike an arc in any one of the 4 glass systems built.

Hypotheses to Explain Non-Arcing

Hypotheses to explain this new characteristic of the arc, at least for the iron arc in argon, were offered following presentation of these results at the 1932 A. I. E. E. winter convention by Dr. K. T. Compton, Dr. Saul Dushman and Dr. Joseph Slepian. Because of their considerable theoretical interest, these hypotheses are stated in the following paragraphs.

In commenting on the inability to obtain the normal arc under these "drastically purified" conditions, Dr. Compton in a private communication suggests that possibly an oxid layer on the cathode is a prerequisite in maintaining the proper cathode temperature (in accordance with the thermionic emission theory of the arc). Such an oxid layer might raise the cathode temperature by virtue of its electrical resistance or its thermal insulating properties. Compton further suggests that the elastic electron impacts with argon molecules might so scatter the current over the cathode as to make impossible the establishment of a cathode spot.

Dr. Dushman in a private communication, also considering the arc in terms of thermionic emission, remarks that a thin film of iron on an oxid surface of the metal has a far greater thermionic emission than has the uncontaminated metal surface itself. He is undertaking new experiments in a study of such effects.

Dr. Slepian discussed the subject before the convention in the light of Langmuir's space charge theory. For low current arcs, such as used in the present experiments, the positive space charge just outside the cathode is very small. Consequently, the lines of force of such a charge are spread out so widely that the electric field between the space charge and the cathode is weakened materially. If the field strength drops below a certain value, it is impossible for electrons to be "pulled out" of the cathode, and hence the discharge cannot be supported.

Because of the indicated basic nature of the discovery these experiments are being continued as part of a comprehensive program, both in America at Lehigh University and abroad in Berlin whence the junior author of this report has gone to continue certain phases of the work. It is contemplated that a complete, detailed report on the studies of the pure iron arc in argon may be published soon by the AMERICAN WELDING SOCIETY. Concurrently, the efforts to determine the properties of pure iron welds are being continued; welds of pure iron and also welds of commercial steel have been prepared in "impure" argon and in air. The chemical, physical, mechanical and metallurgical properties of these welds now are being ascertained.

The work at Lehigh has been carried out in the laboratories of the physics department without whose generous cooperation many phases of it would have been impossible.

[5] *Phys. Rev.*, 21, 266 (1923).
[6] *G. E. Rev.*, 26, 735 (1923); *Science*, 58, 290 (1923).

Discussion of Paper, "X-Ray Determination of Stresses in Welds," by John T. Norton

By **ROBT. E. KINKEAD**

†Mr. Norton is with the Massachusetts Institute of Technology. His paper was presented at the Fall Meeting of the American Welding Society, October 3 to 7, 1932. Mr. Kinkead is a Consulting Engineer, Cleveland, Ohio.

PROFESSOR NORTON has produced in this paper a condensed and authoritative statement of the present status of X-ray determination of stresses in welds. The author is gifted to an exceptional degree in the matter of presenting a clean-cut picture of what is known and what is yet to be learned. His work in connection with the behavior of metals at high temperatures is well known and the Society is fortunate to have the benefit of his efforts in this new field.

The whole subject of internal strains in welds, or for that matter in unwelded metal, is one about which we

have had a great deal of conversation, printed and otherwise, but very few fundamental facts. As the author points out, we have had extremely crude methods of exploring and evaluating conditions of internal strain. The original work with interpretation of transmission and reflection patterns initiated by Prof. Westgren and Dr. Phragmen of the University of Stockholm holds the promise of placing at our disposal a method of measurement of such strains. It seems unnecessary to emphasize that until we get a method of measuring internal strains, we are not going very far with a scientific exploration of the subject.

Enthusiastic and comprehensive work in this field has been done by Prof. G. L. Clark of the University of Illinois. Particularly significant work has been done by Dr. Kent Van Horn of The Aluminum Company of America. As information and data accumulate from these workers and others, we are getting a better understanding of the information conveyed by these patterns. If we are somewhat puzzled at the moment, it is perhaps due to the fact that we need more information which will presently appear.

Examination of the patterns shown in Fig. 5 by the author illustrates very well indeed the fact that we are acquiring ideas as a result of this work which do not connect up very well with our previous beliefs in connection with internal strains in metal. Assuming that the original sample was reheated to 550° C. in one case and 900° C. in the other case, it is certainly a source of astonishment to find about the same degree of asterism striations after heating to 550° C. and find them still noticeable after reheating to 900° C. Similar results have been shown by Prof. Clark and others. Recalling that asterism in the patterns constitutes evidence of plastic deformation, we are at a loss to explain from our present knowledge how such high strains could remain after heating to these temperatures. There are some clever explanations but, to our knowledge, no proven facts. It has been shown that complete re-crystallization under laboratory conditions does remove all strains and the pattern shows a random aggregate. We have a more or less accurate knowledge of the stress-strain characteristics of mild steel at various temperatures and from this knowledge can make at least a logical estimate of how much strain can be removed by reheating to a predetermined temperature and cooling slowly at a uniform rate. Such estimates indicate a very much lower degree of internal strain than is shown by the X-ray patterns. From this point of view, the conclusions drawn from the X-ray patterns simply do not make sense. But if we are actuated by a reasonable degree of scientific curiosity, we have worked ourselves into a delightful situation. We have two sets of well-authenticated facts about the same situation which do not agree at all.

Speaking for ourselves, we feel irresistibly drawn toward a further study of the facts disclosed by the X-ray patterns in the hope that the apparent discrepancies may be cleared up. If we are not yet in a position to use the X-ray patterns to diagnosticate difficulties in and around welds due to internal strains, we appear to be in a fair way to learn more about such conditions. That we are pitifully ignorant of the laws governing the deformation of crystal aggregates has been pointed out by the author. It seems to us that we are also involved in unsolvable problems of applied mechanics as related to the forces set up among the crystals due to changes of temperature, chemical composition and physical properties. We seem to be dealing with unpredictable phenomena. But the X-ray patterns hold out the promise that we can find out what actually happened after the event has taken place.

Automatic Welding with Heavily Coated Electrodes

By LAURENCE R. LEVEEN

†Paper was presented at the Fall Meeting of the American Welding Society in Buffalo, Oct. 6, 1932. Mr. Leveen is connected with the Welding Engineering Dept., General Electric Co.

MACHINE welding with heavily coated electrodes is the natural outgrowth of the successful application of heavily coated electrodes in hand welding. Heavily coated electrodes give increased tensile strength, greater ductility, denser metal and more resistance to shock loads than the same welds with bare electrodes. An automatic head for welding heavily coated electrodes is now available for production purposes.

The inherent nature of the heavy flux coating divides the problem of machine welding into two phases: first, suitable electrodes; second, proper equipment to feed the electrodes and introduce current into the base wire. This latter problem was rather difficult as the question of the proper means of introducing current, from the standpoint of operating cost alone, required considerable time and study to place it on a low cost basis.

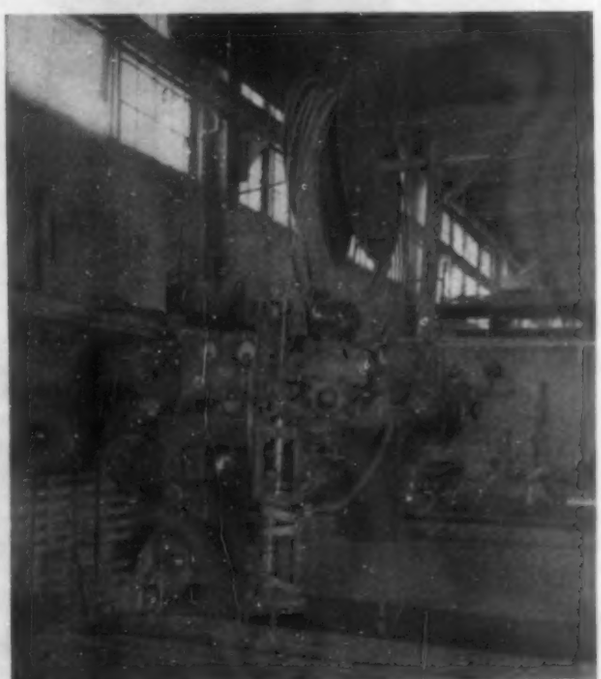


Fig. 1—Arm Type Contact Mechanism for Automatic Head for Heavily Coated Electrodes

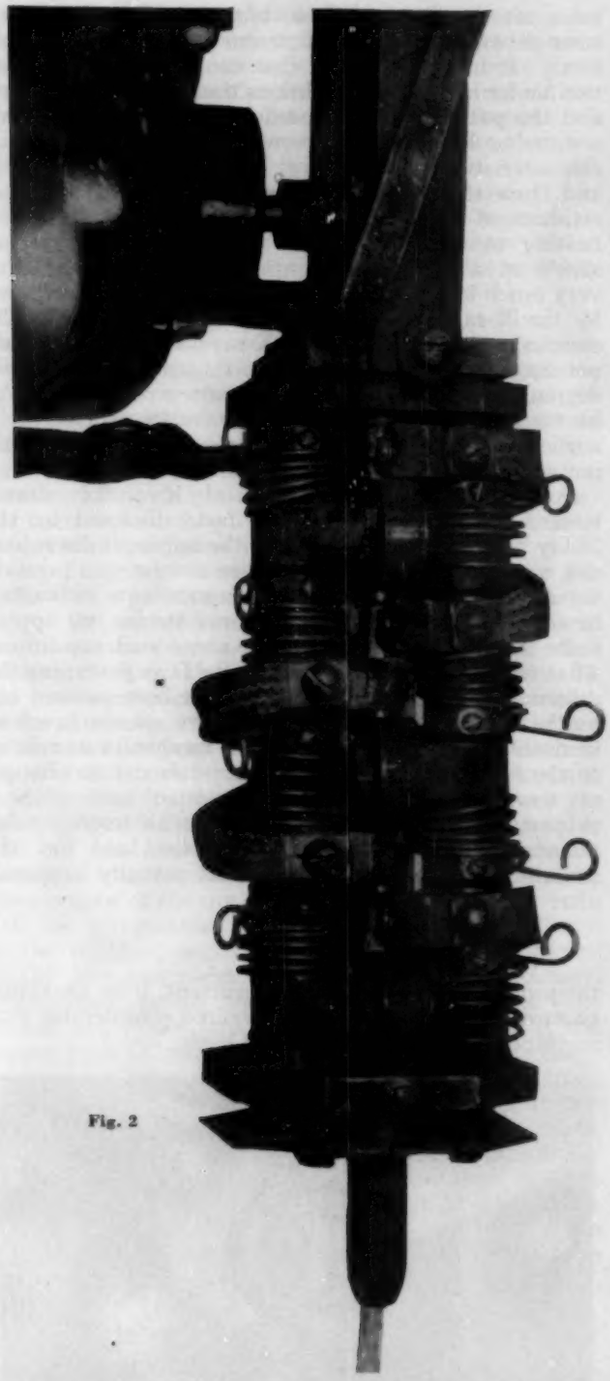


Fig. 2

For machine welding, one of the major requirements of the electrode is to have a coating which will not flake or crack off when wound in coils and fed through the welding head. The idea of using stick electrodes in long lengths and introducing current at the outer end is not desirable from a production standpoint due to the heating effect in lengths greater than fourteen inches. It is much better to have the electrodes furnished in standard coils, and introduce the current close to the arc. The electrode used in the process described here is of the reinforced coated type, that is, it has threads interwoven in the coating.

The welding head used is the well-known magnetic clutch type enlarged and strengthened for the heavier duty required and with the addition of multiple drive rolls, together with the current conducting unit, all combined into one piece of equipment. Referring to Fig. 1, the head is mounted on a standard travel carriage with the electrodes in coil form shown in a loose fashion for purposes of illustration. In practice, the electrode is furnished in 150-lb. coils which are placed on a demountable reel for use, which eliminates the necessity of shipping empty reels back to the point of manufacture.

The electrode is fed from the reel through multiple feed rolls, which engage the electrode on the outer surface of the flux coating, past the high speed cutter which removes a portion of the flux material, as shown in Fig. 1, thus exposing a smooth bright contact surface on the base wire. The electrode then passes through the current conducting unit, shown in Fig. 2, which comprises five sliding contacts backed up by three pressure rolls to keep the electrode in alignment. From this point, the electrode passes through a short guiding nozzle to the arc.

The electrode can be oscillated or not, as the case may be, with an adaptation of the standard oscillator so that practically any welding condition can be met in practice.

This type of unit gives the best performance from the standpoint of ease of handling and low operating cost. All of the necessary requirements for making a good weld are combined in one simple operation.

The feeding of the electrode through multiple feed rolls permits very close arc control for any particular voltage setting. Voltage control is just as simple as for bare-wire welding.

Typical operations from practice show higher speeds than with bare-wire welding and at the same time giving all the desirable characteristics of heavily coated electrode welds.

Some typical examples are given below:

$^{3}/_{16}$-in. plate, butt weld, with no bevel, spaced $^{1}/_{16}$ in. and welded on a backing bar at a speed of 18 in. per minute using $^{1}/_{4}$-in. electrode with 380 amperes and 37 volts. Full penetration was obtained.

$^{3}/_{8}$-in. plate, butt weld, 60° bevel butted tightly together and welded on a backing bar using two welding heads with $^{1}/_{4}$-in. electrode. A net speed of 9 in. per minute was obtained with full penetration, the first pass being made with 375 amperes at 30 volts with no oscillation, and the second at 330 amperes at 34 volts with six and one-half oscillations per in. of weld.

On a 3 $^{1}/_{2}$-in. axle housing, having $^{3}/_{8}$-in. wall with approximately 60-in. bevel, $^{1}/_{16}$-in. shoulder, no spacing and no backing bar, $^{1}/_{4}$-in. electrode was used with 350 amperes at 32 volts and the travel speed was 12 in. per minute with 75% penetration, which was all that was required for this job.

One of the most difficult jobs was the joining of $^{1}/_{4}$-in. plate and a $^{1}/_{2}$-in. plate with a $^{3}/_{8}$-in. fillet weld on a leak-tight job where the deposited metal had to conform to Class 1 Code Requirements; $^{3}/_{16}$-in. diameter electrode was used with 180 amperes at 27 volts with 6 in. per minute travel speed, resulting in full penetration at the root of the weld.

All of the above cases were welded with reverse polarity. The electrodes used in the above job met all of the Class 1 Requirements of the A. S. M. E. Boiler Code, when tested according to its conditions. The reduced section tensile values range 60,000 to 70,000 lb. per sq. in., with free bend results from 35 to 50%. The all-weld metal tensile results range 65,000 to 70,000 lb. per sq. in. with an elongation in 2 in. of 25 to 35%. Specific gravity ranges 7.82 to 7.84.

The results to date with the automatic head designed especially for handling heavily coated electrode, open up wider application for welded products throughout the industries.

Elevated Temperature Tests of Arc Welds in Russia

By B. M. SHIMKIN

RECENTLY in the welding laboratory of the Institute of Metals at Leningrad (Russia) tests were made of welded specimens at elevated temperatures. The result of these tests is published in the May 1932 *Autogenoe Delo*.

The article is very interesting for American welding specialists because similar tests were performed during 1927–1928 by the San Francisco Section of the AMERICAN WELDING SOCIETY at Stanford University laboratory and the report was published in the September 1928 JOURNAL OF THE AMERICAN WELDING SOCIETY.

In Russia a base metal of 0.1 carbon steel plate was taken and all tension tests were produced in 68, 212, 392, 572, 752 and 932 deg. F. on Gagarin testing machine, which gives large scale grapho-diagrams of tension.

The test specimen had $^{5}/_{16}$ in. (8 mm.) dia. and 1 $^{31}/_{32}$ (50 mm.) length between the screwed heads as shown by Sketch *A*.

Table 1 shows the results of the tests on this base metal in elevated temperatures. It can be seen from the table that the ultimate strength of the specimens at 68 deg. F. and 212 deg. F. are the same, then an increase is indicated from 392 deg. F. to 752 deg. F.

The percentage of minimum elongation values decreased to 392 deg. and increased in higher temperatures.

The percentage of reduction of area changed in value similar to the percentage of elongation. For studies of physical properties of weld metal (welding rods) specimens were made from bars which were formed entirely by depositing filling metal on the steel plate and then machined to the size and shape of base metal specimens (Sketch *A*).

The welding rods were $^{5}/_{16}$ in. dia. and had the following analysis: carbon, 0.09%; manganese, 0.04%; sulphur, 0.035%; and phosphorus, 0.016%.

A direct current of 160 amperes was used for welding. The data for filled metal specimens are shown in Table 2.

The changing of ultimate strength was about the same as for base metal. The elongation and reduction of area for filled metal were very small. The center part of two fire-box plates single vee welded together was used for making specimens for the test of welded specimens in elevated temperatures. (See Sketch *B*.) The size and shape of these specimens were the same as for previous tests. The same electrodes were used.

The results of such test are shown in Table 3. All fractures were at welds.

By the comparison of all three tables it can be seen that arc-welded specimens have about the same ultimate strength as base material and filled metal, but a very poor ductility especially at 392 and 572 deg. F.

The very small reduction of area creates the impression that arc-welded seams are brittle at high temperatures.

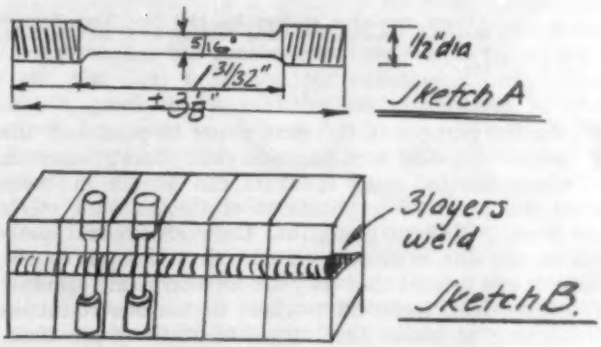


Table 2—Physical Properties of Weld Metal at Elevated Temperatures

Temp. in deg. F.	Propor. Limit in Lb. per Sq. In.	Ultimate Strength Lb. per Sq. In.	Elongation in Per Cent	Area Reduction in Per Cent
68	32,800	50,500	8.6	10.0
212	28,800	50,480	8.4	8.5
392	30,600	58,000	6.0	5.0
572	25,600	59,000	4.5	5.0
752	18,900	43,000	6.0	8.0
932	9,950	18,600	12–17	15.0

Table 3—Physical Properties of Welded Specimens at Elevated Temperatures

Temp. in deg. F.	Propor. Limit in Lb. per Sq. In.	Ultimate Strength Lb. per Sq. In.	Elongation in Per Cent	Area Reduction in Per Cent
68	30,000	47,200	4.0	
	34,800	46,000	2.0	
212	34,000	50,600	7.3	
	31,000	45,700	7.8	
392	28,500	44,500	2.2	
	28,500	53,200	6.9	About
572	28,550	56,900	1.8	1.2–1.5
	26,800	63,600	4.4	
752	18,900	49,500	2.6	
	16,500	54,750	3.3	
932	11,800	32,500	5.6	
	11,500	26,800	7.0	

Table 1—Physical Properties of Base Metal at Elevated Temperatures

Temp. in deg. F.	Propor. Limit in Lb. Per Sq. In.			Ultimate Strength Per Sq. In.			Elongation in Per Cent			Area Reduction in Per Cent		
Specimens	1	2	3	1	2	3	1	2	3	1	2	3
68	30,580	36,980	34,135	47,250	53,500	53,052	39.5	30.9	29.0	69.8	67.3	65.0
212	30,153	36,270	34,136	45,000	53,750	54,250	26.4	19.4	14.3	65.8	62.4	59.7
392	27,200	34,136	30,600	59,050	67,500	61,600	21.0	18.6	17.5	57.8	53.7	54.7
572	22,900	32,800	28,500	59,000	66,200	63,400	30.0	27.3	25.3	59.7	57.4	57.0
752	....	....	....	44,600	49,900	42,900	36.2	33.9	34.4	70.7	69.4	70.1
932	....	....	....	30,000	33,000	27,000	45.3	37.6	41.8	77.8	77.0	79.0

Stainless Steels and Irons

By J. H. CRITCHETT

†Paper presented at May 24, 1932 New York Section Meeting, American Welding Society, by J. H. Critchett, Vice-President, Union Carbide & Carbon Research Labs., Inc.

IT IS the purpose of this first paper to point out the broad historical and metallurgical background on which the following speakers can sketch in more detail the practical applications of the stainless steels and irons. Without going into the controversial question of the one man or men who first thought of the steels, it can be said that they are an interesting example of independent technical workers in various countries all arriving at about the same end at the same time.

Undoubtedly development of the economic manufacture of low-carbon ferro-chromium was a pre-requisite to the discovery of the high chromium steels. Sir Robert Hadfield investigated chrome steels in the early 90's and surely would have found their stainlessness properties had he been able to obtain ferro-chromium of sufficiently low-carbon content. However, it was not until Goldschmidt in Germany and Becket in this country had brought out their methods of making low-carbon ferro-chromium that metallurgists could take up the study of the whole range of chromium steels under conditions favorable to the discovery of the stainless property of some of them.

But this does not detract in the slightest from the credit due to those who first found stainless steel. The works of Brearley in England on the stainless steels for cutlery and similar purposes, of Haynes in the United States on stainless steel and iron, of Clement also in this country on the low-carbon stainless irons and of Strauss in Germany on the nickel-chromium steels all were independent though concurrent; and the present high chromium steel industry is founded on their results. While giving full credit to those already mentioned for their early part in the development, we should not forget the work of Doctor F. M. Becket on the steels of over 20% chromium content, Doctor C. M. Johnson's early study of the nickel-chromium-silicon steels and Doctor W. H. Hatfield who seems first to have appreciated the value of the present most popular 18% chromium-8% nickel analysis, especially in the austenitic condition, and many others.

Basically, the stainless steels and irons are iron-chromium alloys of over 11.5% chromium content. Other elements may be added, such as nickel, manganese, silicon, tungsten, and the like, but the property of stainlessness is dependent on the chromium content and the added element only modifies this in one direction or another or affects the physical properties. Stainless iron is the plain chromium steel of low-carbon content while stainless steel contains usually in excess of 0.20% of carbon.

When chromium is added to carbon-free iron, the first small percentages have very little effect on the resistance of the alloy steel to corrosion. When as much as 3% of chromium has been added, corrosion resistance is appreciably improved. With about 5% chromium content this improvement is sufficiently marked so that an important class of steel is now being made containing about this percentage. However, the improvement in corrosion resistance is gradual until the steel contains in the neighborhood of 11.5% of the element. At this point a sudden and vertical rise occurs in the corrosion-resisting properties. It happens that this amount of chromium is sufficient so that each molecule of metal can contain one atom of chromium and to this fact is attributed the sudden improvement in corrosion resistance at this percentage. Apparently so long as molecules of iron can exist in which there is no chromium, corrosion can proceed by attacking the chromium-free molecules. When each molecule contains its protective chromium atom, then corrosion cannot proceed through any unprotected iron molecules; hence, the sudden improvement in corrosion-resisting properties. From 11.5% upward additional chromium gradually continues the improvement in corrosion-resistant properties until sufficient has been added so that there can be two atoms of chromium in each molecule of iron. Above this amount additional chromium confers benefit only for a few special applications.

Actually, the iron-chromium alloys are not resistant to corrosion in themselves. This property depends upon a thin oxide film which is transparent, dense, tightly adherent and extremely resistant to a large number of atmospheric and chemical corroding media. Whenever broken by abrasion or a scratch, the film instantly reforms and prevents progressive deterioration. That this film is actually present even on the steels polished to a mirror surface has been proven by Evans in England who has been able to remove and study them. While we may not be particularly interested in such rather abstract theory, this fact has a practical application in that the chromium steels in general are not so strongly resistant under conditions where corrosion is accompanied by action which tends to continuously remove the film as it is formed. Such conditions are extremely rare, however, and the steels find wide application as will be learned from the two speakers who follow.

As to the metallurgy of the plain chromium steels, I shall, in order to keep within the limits of the time available, leave out all reference to the manufacturing and rolling procedures. The subject would require more time than available and this audience, I take it, is more interested in the fabrication and use of the steels; hence, I shall attempt to speak only of the metallurgy affecting these operations. Fortunately the manufacture of these steels is in the hands of thoroughly competent steel makers and very few troubles arise from this source. One thing very carefully watched by the producers and of real importance to users is cleanliness. Since the corrosion-resisting properties of the steel depend on a film, as just described, anything tending to make a discontinuity in this film affects the usefulness of the steel. Certain types of inclusions, such as silicates, do not seem to be very harmful but those of the oxide type serve as centers from which corrosion can start.

The stainless irons; that is, the steels with a low-carbon content, are ferritic—very analogous to plain carbon steels. Iron and chromium form a solid solution which behaves in much the same manner as the pure iron phase, and carbon forms a carbide analogous to the iron carbide phase in plain carbon steel. As a consequence, they respond to heat treatment in much the same manner as carbon steel, that is, they may be hardened, tempered and annealed. In this way the

physical properties may be considerably altered so as to adapt them to many varied applications though generally they are used in the fully annealed condition since they are more easily fabricated in this condition. The relation of the amount of carbon present to the chromium content determines the extent of the response to heat treatment. In general with low carbon they do not harden appreciably. With higher carbon they do harden and can be given increased tensile strength by proper heat treatment. With increasing chromium content, more and more carbon is required to make these steels susceptible to heat treatment until with the over 20% chromium variety there is little hardening even with as much as 0.35% carbon. The temperature required is dependent somewhat upon the exact chromium and carbon analysis and varies from 650 to 800° C., that is, metal slowly cooled from these temperatures is soft and ductile, whereas, when quenched from these temperatures, it becomes harder, stronger and somewhat less ductile. Another factor which must be borne in mind in the heat treatment of high chromium steels is their relatively sluggish rate of reaction at temperature. Because of this fact, they must be held either for a considerable length of time at minimum temperature capable of causing the metallurgical change, or the temperature must be raised considerably above this minimum.

There is one important result of carbon in these steels which is not present in plain steel. As mentioned, as the chromium content is increased, there is a sharp increase in the corrosion resistance of pure iron-chromium alloys at about 11.5% chromium content. Carbon in the stainless irons combines with the chromium and abstracts it from the iron-chromium solid solution, thereby lowering the percentage of chromium effective in producing stainlessness. Since one part of carbon fixes approximately ten parts of chromium, 0.10% carbon content in these stainless irons is equivalent to a reduction of 1% in chromium content as far as stainlessness is concerned. This situation is aggravated by the relative immobility of the atoms so that in the neighborhood of carbide particles the chromium in solid solution is lowered much more than would be calculated from average analysis figures, and hence the stainlessness in these localities is impaired. To overcome this local action, the chromium content must be increased sufficiently above the theoretical lower limit to offset the effect of the carbon content.

In the true stainless steels, such as are used for cutlery, pump shafts and similar applications where hardening is required to give suitable properties, chromium is held somewhat to the low side of the range under discussion; that is, around 12%, and the carbon increased to about 0.30 to 0.35. Such steels take the temper practically equivalent to carbon tool steels and are strong and resilient. However, in order to obtain true stainless properties, the surface must be carefully polished.

With over 23% of chromium content, there is a second sudden increase in the corrosion resistance against many corroding media. Particularly is this true of the resistance to oxidation and scaling at high temperature. As a matter of fact, all of the high chromium steels resist scaling and oxidation and the resistance is good at increasing temperatures as the chromium content is raised. These steels also maintain a useful degree of strength at much higher temperatures than ordinary carbon or low-alloy steels.

The plain chromium steels are so varied in composition and so dependent on heat treatment that the task of giving a comprehensive idea of their physical properties is quite hopeless. In general, in the annealed condition they have nearly twice the strength and elastic limit of boiler plate, are as soft and ductile and can be worked and fabricated by the methods used for ordinary steel. They can be readily machined, punched, drilled, formed and drawn. Riveting is very satisfactory but is usually done with rivets of a somewhat modified composition. Special fluxes make silver soldering, brazing and ordinary soldering and tinning possible. Welding can be by either the oxyacetylene or electric method though special fluxes and technique are advisable. It should be noted, however, that where heavy sections are welded, there is a tendency for grain growth and where the corroding conditions are very severe, the welded article should be heat treated after welding to put it into the best condition for resisting attack. There are a great many varieties and conditions in these steels but there need be no confusion. They are well known by many metallurgists as a result of the last ten years' work.

A most popular variety of high-chromium steels today is that in which the properties of the basic chromium steels have been modified with nickel, the particular variety used in great tonnage being the so-called 18–8% referring to the chromium and nickel content, respectively. Actually, in these steels the resistance to corrosion of the basic chromium steels is enhanced by the nickel content and they become resistant to a greater variety of corroding media. For use they are invariably put into the austenitic condition, that is, the condition in which all of the constituents occur in a single solid solution phase. As a result in practice, the physical properties are not modified by heat treatment but are those inherent in the analysis. The strength, however, can be materially increased by cold working without seriously affecting the corrosion resistance.

While nickel is most commonly used to produce the austenitic steels, manganese also is capable of producing them and when used should be present to the extent of about 9%. Another very good variety of steels contains both manganese and nickel to the extent of 4–5% of each. In a sense these steels do not depend upon carbon content for their physical properties. However, there is a limit to the amount of carbon that can be put into solid solution, hence, this element is kept quite low, say, under 0.16 and for some uses under 0.10%.

One of the unique properties of these austenitic steels is that they are practically non-magnetic, a fact which makes them applicable to a number of uses in the electrical industry. Otherwise their physical properties are quite analogous to carbon steel. They have a yield point of about 40,000 lb. per sq. in., an ultimate strength of about 90,000 lb. per sq. in., an elongation of 30% or more and a reduction in area of 60% or more. When cold worked, as by cold rolling or wire drawing, both elastic limit and ultimate strength are increased by an amount depending upon the degree of cold work. By this means it is possible to get an ultimate strength of 150,000 lb. per sq. in. or more but, of course, with some sacrifice of ductility. In the normal condition these steels have very good ductility and can be deep drawn and spun and otherwise treated by methods that require a high degree of softness. In all operations of this type, however, it must be kept in mind that these steels, like other austenitic steels, work harden and that this condition must be relieved occasionally before further work is carried on.

The welding properties of the composition are exceptionally good either by the gas or electric method. For much work it is not necessary to heat treat subsequent

to welding, although where the corrosion is very severe it is preferable to do so. The most recent advance in the austenitic steels has been the discovery of a means of overcoming inter-crystalline corrosion. The difficulty has occurred only in uses such that these steels are held at certain definite temperatures in the neighborhood of 600° C. for a very long time. By the addition of titanium or columbium, it has been found possible to so modify this popular variety that even that trouble has been overcome.

Stainless Steel

By C. A. SCHARSCHU

†Paper presented at May 24, 1932 New York Section Meeting, American Welding Society, by C. A. Scharschu, Director of Research, Allegheny Steel Company.

ORIGINALLY the name "Stainless Steel" was coined to describe the high-carbon chromium-iron alloys within a definite range of composition. Later the low-carbon chromium-iron alloys and the chromium-nickel-iron alloys were developed, and as these also possessed "Stainless properties" they were also called "Stainless Steel." Hence "Stainless Steel" is no longer a name referring to a definite material, but a generic term embracing a whole series of chromium-iron and chromium-nickel-iron alloys of widely different physical and corrosion-resistant properties. So it is necessary that when the use of stainless steel is contemplated, that the conditions of service must be definitely known and that composition selected whose properties are most suited to the kind of service which is to be encountered.

The more common types of stainless steel of similar properties have been arranged into groups, and the manufacturers of these steels have generally accepted the same composition limits for each of these groups, particularly in regard to carbon, chromium and nickel content. The composition limits for these groups are:

I	Carbon under		0.12%	Chromium	12–15%		
II	"	"	0.12%	"	15–18%		
III	"	"	0.12%	"	18–23%		
IV	"	"	0.12%	"	23–30%		
V	"	approximately	0.3%	"	12–14%		
VI	"	"	0.6%	"	16–18%		
VII	"		0.05–0.20%	"	16–20%	Nickel	7–10%
VIII	"	under	0.20%	"	20–30%	"	10–20%

Groups V and VI, the high-carbon chromium steels, are used chiefly for cutlery, and their properties will not be considered. Groups III, IV and VIII are chiefly used, not because of their stainless properties, but because of resistance to oxidation at high temperatures.

Manufacture

The bulk of these steels is melted in the electric furnace of the arc type from a good grade of scrap which is further refined under basic slags to eliminate harmful impurities before the addition of ferro-chrome and nickel is made. While each manufacturer undoubtedly has his own special method for the melting, refining and finishing of these steels, based upon his own experience and local conditions, yet the practice in general closely follows that used in the making of high-grade tool steels. After the steel has been refined, it is carefully deoxidized and degasified in order to produce a product as free from oxides and other non-metallics as possible.

These steels are all more difficult to roll than common steels and a great deal of care must be exercised at every step in the rolling process to produce material which is free from surface defects. In common steel the ingot is usually rolled direct into the finished product, sometimes with only a single heating, or at best with only a few heatings if the finishing operations are carried out in different mills. Usually combinations of pickling and cold rolling give a surface which is satisfactory for most purposes. This, however, is not the case with the stainless steels. They have a greater tendency to crack and tear in the rolling operations, so that it becomes necessary to clean up the billet either by chipping, grinding or turning at several stages in the rolling operation to obtain good surface. Up until a short time ago, it was the general practice in European countries to machine all ingots before the rolling was started. About $^3/_8$ in. of the surface of a 12 x 12 ingot was removed or about 12% of its weight to insure a satisfactory product.

Available Types

All of the types of stainless steel which I have shown in the eight groups are available and are regularly produced. The most important steels of this group are the 12–15% chromium, the 15–18% chromium and the 16–20% chromium with 7–10% nickel. For special purposes, small amounts of other metals such as silicon, molybdenum, tungsten and titanium are added. These additions change the characteristics of these alloys very little at ordinary temperatures, and for those applications with which the architect has to deal, are very rarely used. The corrosion resistance of these steels is in the order named, the 12–15% chromium steels being the least resistant and the 16–20% chromium with 7–10% nickel the most resistant. The 12–15% chromium steels when exposed to the atmosphere will be covered with a tightly adherent rust which gradually turns black and which in this condition will resist atmospheric corrosion for many years. Samples of this material have withstood the Pittsburgh atmosphere for seven years with no signs of progressive corrosion or pitting. Alloys with 15–18% chromium are still more resistant. The alloys with 16–20% chromium and 7–10% nickel are not only extremely resistant to atmospheric corrosion, but will not tarnish, and will keep their original luster for a long time. Their surface, of course, will become dirty and dull from the dirt which collects. Washing, however, with soap and water to remove the grease and dirt which collect is all that is necessary to restore their original luster.

Physical Properties

The physical properties of the stainless steels or rather stainless irons, because the low-carbon alloys are invariably used, should prove extremely interesting to the architect and engineer because the alloys of Group I, carbon under 0.12% and chromium 12–15% are perhaps the most ideal engineering materials known. They respond to heat treatment, and because they readily air harden, a wide range of physical properties may be obtained with a relatively inexpensive and simple heat

treatment. By suitable treatment, tensile strengths ranging from 65,000 to 180,000 P. S. I., elastic limits from 40,000 to 160,000 P. S. I. and elongations of from 15 to 37% may be obtained. The hardness range for these alloys is from 140 to 360 Brinell. In the annealed state, the tensile strength will run from 70,000 to 85,000 P. S. I., elastic limit 40,000 to 50,000 P. S. I., elongation 30–37%, reduction of area 70–78% and Brinell hardness of 140–170. Hardened to 200–225 Brinell, a tensile strength of 100,000 P. S. I., true elastic limit 70,000 P. S. I., elongation 25% and an Izod impact value of 80–100 is obtained. The coefficient of expansion of these alloys is about the same as that of steel, electrical resistance about 60 microhms per cu. cm., specific heat about 0.159. They resist oxidation at elevated temperatures very well and may be used up to 1500° F.

These alloys are suitable for drawing and forming operations and, except in the hardened condition, may be quite readily machined. Where parts are to be machined at high cutting speeds, such as on automatic screw machines, sulphur is introduced either as sulphur or as a sulphide of zirconium, molybdenum, manganese, etc. to the extent of about 0.15 to 0.25%.

The alloys of Group II, namely, carbon under 0.12% and chromium 15–18%, respond less readily to heat treatment than the alloys of Group I and only a limited range of physical properties can be obtained by heat treatment. They are principally used in the annealed state. In this condition, typical physical properties are:

Tensile Strength	65,000–85,000 P. S. I.
Yield Point	40,000–55,000 P. S. I.
Elongation in 2 In.	20–35%
Brinell	130–160

By oil quenching from 1800° F., hardness values of about 300 for the lower chromium alloys and about 225 for the higher chromium alloys may be obtained. Air cooling, however, from this temperature gives hardness values of about 275 for the lower chromium alloys and about 200 for the higher chromium alloys.

The coefficient of expansion of these alloys is roughly about the same as that of steel, their impact value is lower than alloys of Group I, the electrical resistance will range from 60–70 microhms per cu. cm., weight per cu. in. of about 0.278 lb.

These alloys are suitable for forming and drawing operations and may be machined quite readily, For rapid machining, a modified alloy with high sulphur content has been developed similar to those of Group I.

Alloys of Group III and Group IV respond only to a very limited extent to heat treatment and are not suitable for fabrication involving difficult drawing and forming. Their principal use is at elevated temperatures where they resist oxidation to a remarkable degree, although they are used in very special cases for service at low temperatures on account of their excellent resistance to corrosion.

For alloys in Group III, the following physical properties are typical:

Tensile Strength	79,000 P. S. I.
Yield Point	48,000 P. S. I.
Elongation in 2 In.	25%
Reduction of Area	60%
Brinell Hardness	150

Air hardened from 1800° F., the Brinell hardness of only 180 was obtained.

For alloys in Group IV, typical properties are:

Tensile Strength	75,000–100,000 P. S. I.
Elastic Limit	45,000– 60,000 P. S. I.
Elongation in 2 In.	25–35%
Reduction of Area	45–65%
Brinell Hardness	160–200

Alloys in Group IV will give good service at temperatures up to 2100° F.

The alloys of Group VII, C. 0.05 to 20%, chromium 16 to 20% and nickel 7 to 10% are the alloys which are generally referred to as "Stainless Steel" and are quite commonly known as 18–8. These alloys are very different from the straight chromium alloys just considered. They are non-magnetic and cannot be hardened by heat treatment.

In the annealed condition, typical physical properties are:

Tensile Strength	80,000–100,000 P. S. I.
Proportional Limit	25,000– 35,000 P. S. I.
Elongation in 2 In.	55–70%
Reduction of Area	65–80%
Brinell	135–150

Rounds and flats may be obtained with higher physicals by working the alloy at a lower temperature and not annealing after the hot rolling operation. Tensile strengths of 150,000 P. S. I. may be obtained on bars of small size and somewhat less on bars of larger sizes. By cold working and cold drawing, considerably higher physical properties may be obtained. For example, wire may be obtained with a tensile strength of 300,000 P. S. I., and a tensile strength of 250,000 to 275,000 P. S. I. is readily met in cold-rolled strip. In sheets, however, physical properties of much lower values can only be obtained.

Carbon has an appreciable effect upon the physical properties of these alloys. The lower carbon alloys of this series will have a tensile strength of about 75,000 to 80,000 P. S. I., while the higher carbon alloys will have a tensile strength of 90,000 to 100,000 P. S. I.

These alloys have a coefficient of expansion of about $1^1/_2$ times that of steel, an electrical resistance of about 72 microhms per cu. cm., a permeability of 1.02 which by severe cold working may be increased to 1.06 and a weight of about 0.283 lb. per cu. in., which is about the same as steel. They resist oxidation well and may be used at temperatures in ordinary atmospheres up to 1700° F. At elevated temperatures these alloys have very high strength and creep values.

They may be drawn and formed into the most difficult shapes with much fewer operations and anneals than soft steels. For difficult drawing operations, the higher carbon alloys and those with higher alloy content give better results as they have much less tendency to work harden. These alloys can be machined if the tools are properly ground, but they are by no means easily machinable. In order to improve their machining properties, the sulphur, and in some cases the phosphorous content, has been slightly increased either by direct addition of sulphur or phosphorus or some compounds of sulphur or phosphorus. These additions improve the machining properties in a marked degree, but unfortunately, they also decrease, for many applications, the corrosion resistance.

Alloys in Group VIII have the same general characteristics as those of Group VII, which we have just considered. They are used chiefly for high temperature service. They have also been used at normal temperatures where the conditions of service are severe. They are slightly stronger than alloys of Group VII and may be used in ordinary atmospheres at temperatures up to 2100° F. They may be readily formed and drawn.

Welding

The welding of the stainless steels presents no particular difficulty in the welding operation itself, but in

order to insure good welds, the welder must have some experience and instruction, as the electrical resistance, thermal conductivity and, in the case of the 18–8 alloys, the coefficient of expansion are different from that of steel. A good welder, however, after a short time, can readily work out the conditions which give the best results.

These alloys may be welded by the oxyacetylene, electric metallic arc, carbon arc, electric spot, either individual or continuous, electric resistance line weld or electric compression butt methods. In welding, a welding rod is selected of such composition that the deposited weld metal will be of practically the same composition as the alloy to be welded. Coated rods are used for electric arc welding and, for this purpose, it is best that the flux on the rod contain no carbonaceous material which would build up the carbon in the deposited weld metal. Better results are obtained with reversed polarity, that is, the work is made negative and the electrode positive, just the reverse of the conditions used for steel. A short to medium arc is used with only enough power input to maintain the arc.

In the electric spot and compression butt welding, it is advisable to use a minimum power input and to develop the proper pressure and time element for each gage of metal.

In oxyacetylene welding, the first requisite is reliable gages so that the flame may be accurately controlled. An uncoated welding rod may be used. Very careful control of the flame is necessary; it should not be too hard and very slightly reducing. To insure freedom from pinholes and pockets, the weld should not be puddled. Neutral and oxidizing flames tend to produce porous welds while too reducing a flame builds up excessive carbon in the weld which is far from its ideal condition to withstand corrosion. If the proper precautions are taken, perfectly sound and satisfactory welds may be obtained.

With the 18–8 or chrome nickel alloys, there is a greater tendency for the piece to buckle and go out of shape on account of their higher coefficient of expansion. This can be controlled by preheating and by the use of jigs and chill plates and by proper manipulation, in many cases, may be entirely eliminated.

As to which method of welding is preferable, will depend largely upon conditions and the type and gage of the work. Particularly in the case of the 18–8 alloys, the electric method of welding seems more desirable as there is no tendency for carbon pick up in the weld, and it is usually faster and therefore cheaper. The thinner gages of metal, however, cannot be welded satisfactorily by the metallic arc method, and either some type of electric spot or resistance welding or oxyacetylene welding must be used. With proper precautions, it is possible to make good welds by the oxyacetylene method, but much care is required, and it is more difficult to produce satisfactory welds consistently unless the welder has had considerable experience.

The question might be asked as to the physical properties of the welds made and also their resistance to corrosion. With alloys of the first four groups, if the welds are free from porosity and oxide inclusions, they will resist corrosion under most conditions about equally as well as the unwelded alloy. Since the alloys of Group I are air hardening, the welds will be quite brittle and should be annealed in order to obtain sufficient ductility to withstand shock and bending. For many applications, local annealing with the torch may be sufficient to give satisfactory results, but with torch or local anneal, care should be taken so that the temperature does not exceed the critical temperature or these alloys will be hardened, rather than softened by this operation.

The alloys of Group II air harden to a much less extent than those of Group I, so that the welds produced are less brittle, and welded articles may be transported without danger of cracking. The ductility of the welds, however, may be improved by torch or local annealing, or by full annealing if the maximum ductility is desired. Alloys in Group III and IV do not respond to any great extent to annealing, so that the properties of the welded sections are not improved by annealing. These alloys are welded, however, and the welds are satisfactory for the type of service for which these alloys are used.

With alloys in Groups VII and VIII the welds are approximately as strong as the unwelded metal and the ductility is but little impaired. For many applications, no annealing is necessary. For maximum resistance to corrosion, the scale formed in the welding operation should be removed by pickling or grinding.

There are, however, many kinds of service where severe corrosion is encountered, that the welded sections will fail adjacent to the weld. This phenomenon has been described as weld decay. Briefly, when these alloys are subjected to a certain temperature range as in welding, a change takes place which makes them less resistant to corrosion. This critical temperature range will vary with composition but roughly it may be given as 800–1400° F. In all alloys of the 18–8 type, or those in Groups VII and VIII, this change will take place, making them less resistant to certain types of corrosion if they are held long enough in the temperature range given above. This is true for alloys of low-carbon content as well as for alloys which contain small percentages of tungsten, molybdenum, silicon, titanium, etc. This change takes place more slowly with some compositions than with others. In the operation of welding particularly the lighter gages, the time at which part of the section is within this critical range is short and those alloys which require a longer time for this change to take place are necessarily less affected by the welding operation. For this reason, a special grade of alloy is supplied where welding is to be used in fabrication. The 18-8 alloy with carbon under 0.07% is recommended almost exclusively for this field by some manufacturers, while other manufacturers have found that slightly higher carbons with higher alloy content have equally as good stability with an advantage of better physical properties and greater resistance to fatigue. Other types, to which a small amount of another metal, such as titanium has been added, are also recommended by some of the producers.

All of these special types are supplied, where it is not expedient to anneal after the welding operation, but only for certain kinds of service. For the most severe service, I believe that the manufacturers generally recommend that the fabricated article be annealed at a temperature above this range. At the lower temperatures, a very long time may be required. At 1800–1900° F., the time of annealing will be short, with quite heavy sections; one-half hour will generally suffice to completely restore the alloy to its original condition of maximum corrosion resistance. At temperatures above 1900° F., only a few minutes at temperature will be found necessary.

In practically all of the applications in which the architect is interested, the corrosion resistance of these alloys is not sufficiently impaired to make annealing necessary after welding. Atmospheric or salt spray tests do not show any difference between the welded section and the unwelded section of the alloy.

Applications of 18–8 Stainless Steel in Architecture and in the Industries

By D. T. HADDOCK

+Paper presented at May 24, 1932 New York Section Meeting, American Welding Society, by D. T. Haddock, Consulting Engineer, American Sheet & Tin Plate Company.

THE application of this new material of construction and ornamentation is now well established and may be seen in buildings in many localities. Extended and detailed study, tests and applications lead us to believe that 18–8 has a life approaching infinity, even when exposed to the atmospheres of our industrial and seacoast cities. From the standpoint of permanence when subjected to atmospheric exposure, it is comparable to gold and platinum. The corrosion resistance is in the metal itself, that is, there is no thin coating or plating to wear through or to chip off. When applied with the surfaces polished, 18–8 retains its initial white silvery luster indefinitely. No rust or other oxide develops to mar, discolor or hide the original white luster. Frequent polishing is not necessary. All that is required to maintain the original metallic sheen is an occasional simple washing with soap and water to remove the film of dirt and grease, which is always deposited on any exposed material.

The 18–8 is a strong, tough, but at the same time, ductile material. Its mechanical properties are briefly: yield point, 40,000 lb. per sq. in.; ultimate tensile strength, 90,000 lb. per sq. in.; elongation 60%. It can be worked, with the application of proper technique, by all the methods commonly used in working steel and the non-ferrous metals, that is, it can be formed, drawn, spun, machined, soldered, riveted and welded.

The producers are now offering 18–8 in all of the forms available in steel, including sheets, plates, tubes, bars, strip, wire, shapes, cable, nails and castings. It can be obtained in the various fabricated forms common to steel, including rolled shapes, kalamein, forgings, bolts, nuts, rivets, screws, grills, etchings and screens. In fact, 18–8 is now available in all the forms commonly obtained in any of the metals and the alloys used in building construction; 18–8 cannot be extruded like the soft metals, but mouldings with sharp corners, made of heavy or light strips of 18–8, are available, formed by rolling and drawing processes.

Metal fabricators supplying the building trade can produce in 18–8 practically any designs capable of being executed in other metals. Because of its inherent strength and toughness it requires more power for forming operations than do the non-ferrous metals, but this is offset in part by the fact that, because of its strength and toughness, sections thinner than common for the non-ferrous metals may be used. Being a unique material with its individual properties and working characteristics, 18–8 requires its own technique in working. Fabricators are, however, rapidly becoming familiar with it and today a large number of them are capable of turning out work in 18–8 first class in every respect. It is suggested that where contracts for fabrication of 18–8 are let to shops not thoroughly versed in it, these shops be instructed to handle the alloy in accordance with the producer's recommendations.

In fabrication and erection 18–8 should be so handled as to preserve the polish. At present the best way to insure that sheets and most other forms of 18–8 will be stainless in service, when exposed to outdoor atmospheres, is to have the surface polished. By a polished surface we mean a thoroughly cleaned surface, that is, a surface that has been freed from pits and defects. The polish resulting from the thorough cleaning of the surface can be varied at will from a highly lustrous mirror-like finish to the dull grey of the "tampico-brush" finish. Unless the work is to be polished after fabrication and erection, which is seldom practicable, the original polished surface should be carefully protected.

It has been found good practice to passivate the surfaces by immersing the completed piece in nitric acid (20% solution at 150° F. for thirty minutes) followed by rinsing in clear water. Where it is impracticable to immerse the finished work in a tank of acid, it is advisable to swab the piece, particularly the edges, with the acid. This nitric acid treatment, known as "passivation," also dissolves and removes particles of iron and dirt, that have been rubbed on or imbedded in the metal during fabrication.

When stainless steel is to be used on the exterior of buildings where it will be subjected to rough handling, either in the erection of the piece itself or from subsequent construction work which might cause brick, mortar, plaster and miscellaneous substances to fall on the metal, it is recommended that the finished stainless surface be protected by means of a covering of wrapping paper. The paper covering should not be removed until the completion of the building.

The question of cost of work executed in stainless steel is a vital factor in any consideration of its application. The cost to be considered, of course, is that of the completed job, rather than the producer's price on the raw material. Notwithstanding the fact that stainless steel compares only with gold and platinum from the standpoint of retention of color and luster after indefinite exposure, that it is a much stronger and tougher material than most of the non-ferrous metals commonly used for ornamental work, that its real development dates back only a decade and a half, that all fabricators are not as yet adequately tooled up for its handling—the cost of fabricated stainless steel, nevertheless, compares favorably with the cost of the same work in other ornamental materials. At this time, ornamental work executed in 18–8 generally costs 10 to 25 per cent more than the same work in bronze. It should be remembered that we are now speaking of initial costs. If over-all annual costs, which would include cost of maintenance and polishing in order to preserve the metallic luster and color, were considered, stainless steel would prove to be appreciably more economical.

Applications of stainless steel to architectural purposes have already covered nearly everything imaginable; the complete kitchen equipment and plumbing and lighting fixtures of the home; restaurant kitchen and soda fountain equipment and decorations; store fronts, elevator doors and cabs, bank vaults, complete lobby ornamental work, including doors and casement windows; base boards (other materials have been found

not to stand up when subjected to the splashing and mopping common to all of our public buildings), spandrels, double-hung windows, flashings and counterflashings, kick plates; and then, of course, such applications as the dome of the Chrysler Building and the pilasters and mullions, as well as other parts, of the Empire State Building.

This wide range of architectural applications represents in part a direct substitution of 18–8 for other metals. The characteristic of this alloy which has contributed much to its adaptability to such work is its property of retaining indefinitely its color and luster.

We believe that the future development of the use of 18–8 in the building field will be more on the basis of designing for this alloy, rather than attempting to substitute 18–8 in designs formerly executed in the older materials. The adoption of any new material usually follows a certain well-defined path. It is first considered only as a direct substitute for the older materials, and then, as the professions and industry begin to appreciate the individual properties and performance of the new product, it finds a much broader and more logically applied field of usefulness, largely because architects and engineers have begun to think in terms of the new material. The economical adaption of 18–8 in the field of buildings and structures is in the hands of those artists and engineers who have always been willing and eager to fit any new material to its best usage. (By this we speak of the architect, for he is both artist and engineer.) Already there are notable examples of construction in 18–8 which combine both beauty and utility.

In the exhibit you will find one or two models of structural panels which represent advanced ideas of construction that combine both beauty and strength; panels faced with stainless steel, with a backing of commercial semi-rigid and rigid structural and insulating materials, either in board form or concrete. Complete success seems to have attended the efforts of several manufacturers to produce a satisfactory bond between the stainless steel facing and the core material, thereby securing a high degree of water resistance with one kind of core, and a high degree of heat resistance with another. They can apparently maintain a perfect bond notwithstanding the different coefficients of expansion of the metal facing and the core.

While 18–8 is now generally recognized as the leading metal for many applications in various industries, its use in engineering and architecture is comparatively recent, hence, there are as yet but few notable examples. The most spectacular are the Empire State and Chrysler Buildings, which represent the first attempts to use 18–8 primarily as a medium of ornamentation. What can be said as to the feature of utility of 18–8 in construction, as well as beauty? Has this phase of the subject been given proper consideration?

In this connection, some investigations have been made in the interest of utilizing this 18–8 not only for artistic expression but also for carrying out designs that would result in increasing the floor space in buildings occupying valuable ground such as you have in New York City. With that thought in mind the following discussion of spandrels, supported by facts furnished in part through the courtesy of the Maul Company of Illinois, and the Truscon Steel Company of Youngstown, Ohio, are of interest:

Would insulated spandrels with a maximum thickness of 4 in. be practical? Spandrels of 4 in. and, in fact, of thicknesses less than 4 in., are practical. Unfortunately, most building codes require a minimum thickness of 8 in. for spandrels; these codes restrict progress by preventing the elimination of unnecessary bulk. The New York and Chicago codes are being rewritten and, if adopted as now drafted, they will permit a marked reduction in spandrel thickness. It should be kept in mind that the smaller cities have more flexibility in their codes for the adoption of new methods and materials and it is probable in many cases that approval of 4-in. spandrels would be given on specific projects so designed.

Have any standard designs been developed? Yes, a monolithic unit of stainless steel in sheet form, with a backing of concrete, has been developed by a company in Illinois (Macotta Construction) and another type by a leading concern in Youngstown, Ohio (Ferro-Clad Construction). These designs, as shown in several buildings, are convincing in indicating a trend toward convenient standardized units. For a building in Libertyville, Illinois, the architect changed his spandrel design from an 8-in. brick wall to a monolithic stainless steel covered, one-piece spandrel with a minimum thickness of $1^1/_2$ in. and a maximum thickness of 3 in. For additional insulation, 1 in. of insulating material was placed against the back of the spandrel, to which the interior plaster was directly applied. The net saving in wall thickness was 4 in., which afforded an equivalent addition to the floor area. Radiators were placed directly behind the spandrels so that the radiators were not an obstruction in the rooms.

Sometimes the question is raised as to whether stainless steel can be adapted to the construction of continuous vertical sections? One answer is provided by referring to the use of Macotta units in the Richman Brothers' Retail Store Building at Detroit, Albert Kahn, Architect. These stainless steel monolithic sections were employed for the corner and inside mullions, the corner sections extending upward from the base at the sidewalk level, eight stories to the cornice. In work of this kind, $^3/_{16}$-in. joints have been found appropriate. When elastic mortar of light color is used in caulking the joints, a very pleasing effect is obtained. Another answer is provided in the type of construction employed in the Empire State Building, Shreve, Lamb and Harmon, Architects. The pilaster facings are hollow mouldings of formed 18–8 strips, made in lengths of about twelve feet, each length being fitted to and overlapping the next lower section. The total length or height of one of these strips of stainless steel trim is about 928 ft.

The question of the possible use of stainless steel structural shapes for ordinary building construction has been frequently discussed, but the general opinion seems to be that the material is too expensive for this purpose, the saving in weight and increased floor space not being sufficient to justify the increased cost of the chrome-nickel alloys over ordinary open-hearth steel.

Is the use of this 18–8 for building exteriors basically sound, and have past installations justified the extensive use of this alloy? We believe it is, and the continued use is justified by the results obtained to date. In proof of this it may be noted that the pioneer architects who first employed stainless steel continue to specify and recommend it.

Inasmuch as the members of the AMERICAN WELDING SOCIETY are interested in many industries apart from architecture, some of the other fields in which stainless steel is becoming established will be cited.

In the dairy industry the stainless steels are supplanting other materials. The necessity for absolute cleanliness and sanitary precautions in handling milk and its products is paramount, and the importance of milk products and their perishable nature demand the utmost care in their preparation for the market. The

fabrication of milk tanks, pasteurizers, sterilizers and other equipment requires skill on the part of the welder, a technique not acquired in a day.

In the handling and dispensing of food, a fruitful field for 18–8 has been developed. For soda fountains and ice cream cabinets many thousands of tons of 18–8 are now required annually. Service tests conclusively prove that 18–8, due to its silvery and permanent luster, freedom from stain and tarnish, has noteworthy advantages in this field.

In the textile industry, bleaching, dyeing and finishing processes as well as the manufacture of rayon involve a large variety of corrosive substances, for which the chrome and chromium nickel alloys have proved superior to all others in combating destructive action. For the fabrication of equipment such as bleaching and dyeing machines, tanks, containers, rolls, piping, valves, pumps and certain parts of the power equipment, stainless steel has proved its superiority.

In the paper pulp industry, increasing quantities of stainless steel are being required for such applications as blow pit drainers, circulating lines and heaters, digester blow lines, pumps, valves and fittings, facing wires, evaporators, liquor lines, etc. The introduction of chromium nickel alloys is effecting radical changes in the sulphite industry in those departments where new developments have been hampered by the lack of an alloy resistant to the corrosive effect of calcium bisulphite.

In the chemical industry there is another large potential field for stainless steel for the manufacture of high temperature blowers for recirculation of flue gases, reaction vessels, stills, pressure kettles, crystallizers, dryers, digesters, tanks, kilns, kiln liners, blow pit bottoms, relief lines, shipping drums, tank cars, dye vats, bleaching tanks, stock lines, mixing tanks, ducts and pipe lines.

On the whole, the steadily increasing interest in stainless steel and the growing demand for 18–8 on the part of builders and industrialists have afforded a note of encouragement to manufacturers during these days of generally unsatisfactory business conditions.

Committee Report—What Should Be Known by Welding School Graduate

(Committee of the American Welding Society)

Foreword

Welding schools are usually operated by vocational schools in extension classes for specialized trades and general welding classes, trade schools in specialized trades and general welding classes, or universities or colleges in general welding classes with correlated subjects as part of the course. To our knowledge a school organized to carry on a complete welding course treating all phases of the subject in a general manner does not exist apart from training courses offered by manufacturers of welding equipment.

However, even the welding schools who treat welding as a part of their vocational activity should be of sufficient breadth to include training of the students to the point where they would have a general knowledge of the welding and cutting operations including welding technique of all common metals and the materials required to complete welds with all processes.

It is obvious, however, that in a specialized course similar to pipe welding for plumbers and steamfitters, greater interest is taken in pipe welding than in other metals because only pipe is used in their trade, but this does not preclude the advisability of the steamfitter having the same basic fundamental information on welding in general, so that as the welding in his craft expands he will at least know how to develop for himself the necessary technique and where to obtain additional information on his new problem.

Any reputable school undertaking to teach welding should include in its curriculum talks and practices covering the following phases of welding, cutting and bronze welding and each graduate should have a working knowledge of the following:

(*a*) Fundamentals
(*b*) Safety—Rules and Precautions
(*c*) Apparatus—All Processes
(*d*) Supplies
(*e*) Preparations of All Weld Materials
(*f*) Applications
(*g*) Welding—Cutting—Bronze Welding
(*h*) Examinations
(*i*) Tests—Qualifications

Conclusions

Systematic training of the welders in a vocational school or university using well planned and balanced courses with lectures or talks systematically arranged so they dove-tail with the welding practice should produce the best results.

The general knowledge gained by the graduate will naturally be dependent upon the proficiency and knowledge possessed by the instructor and his ability to impart such knowledge, and will be directly proportioned to the number of hours required by the student to complete his course.

The prospects for independent welding schools are not very bright because of the prohibitive fees that would have to be charged to allow operation for profit.

Unquestionably welding and cutting will in time be included in the standard curricula of well-established colleges and universities as a part of their regular courses for engineering students and also for night extension courses for non-students. It is obvious that the best results will only be obtained by such universities or colleges, as the welding course will then be brought up to the standards of other branches of engineering and mechanical courses. When these welding courses are brought up to the standards of engineering and mechanical courses, they will undoubtedly include short courses in correlated subjects which are not available to students taking short extension courses in welding only.

Until a sufficient number of our larger educational institutions are staffed and equipped to include welding courses in their curricula, the best interests of the indus-

try can be served by supporting vocational schools run by the City and State Educational Boards in cooperation with the Federal Board of Vocational Training.

Committee

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